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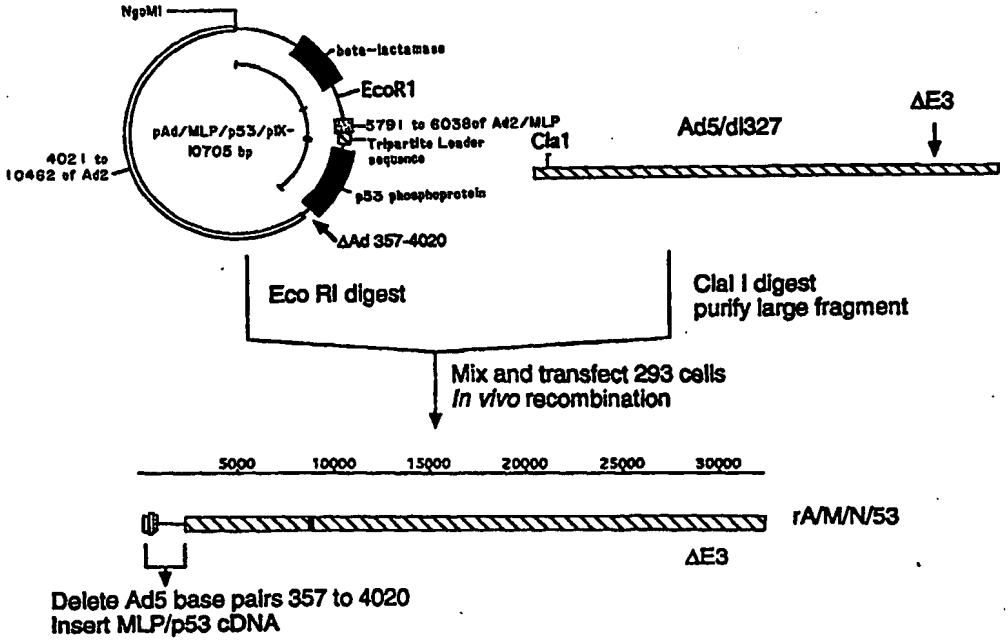

(57) Abstract

This invention provides a recombinant adenovirus expression vector characterized by the partial or total deletion of the adenoviral protein IX DNA and having a gene encoding a foreign protein or a functional fragment or mutant thereof. Transformed host cells and a method of producing recombinant proteins and gene therapy also are included within the scope of this invention. Thus, for example, the adenoviral vector of this invention can contain a foreign gene for the expression of a protein effective in regulating the cell cycle, such as p53, Rb, or mitosin, or in inducing cell death, such as the conditional suicide gene thymidine kinase. (The latter must be used in conjunction with a thymidine kinase metabolite in order to be effective).

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RECOMBINANT ADENOVIRAL VECTOR AND METHODS OF USE

BACKGROUND OF THE INVENTION

This application is a continuation-in-part of U.S. Serial No. 08/233,777, filed May 19, 1994, which is a continuation-in-part of U.S. Serial No. 08/142,669 filed October 25, 1993, the contents of which are hereby incorporated by reference into the present disclosure.

Throughout this application, various publications are referred to by citations within parentheses and in the bibliographic description, immediately preceding the claims. The disclosures of these publications are hereby incorporated by reference into the present disclosure to more fully describe the state of the art to which this invention pertains.

Production of recombinant adenoviruses useful for gene therapy requires the use of a cell line capable of supplying in *trans* the gene products of the viral E1 region which are deleted in these recombinant viruses. At present the only useful cell line available is the 293 cell line originally described by Graham *et al.* in 1977. 293 cells contain approximately the left hand 12% (4.3 kb) of the adenovirus type 5 genome (Aiello (1979) and Spector (1983)).

Adenoviral vectors currently being tested for gene therapy applications typically are deleted for Ad2 or Ad5 DNA extending from approximately 400 base pairs from the 5′ end of the viral genome to approximately 3.3 kb from the 5′ end, for a total E1 deletion of 2.9 kb. Therefore, there exists a limited region of homology of approximately 1 kb between the DNA sequence of the recombinant virus and the Ad5 DNA within the cell line. This homology defines a region of potential recombination between the viral and cellular adenovirus sequences. Such a recombination results in a phenotypically wild-type virus bearing the Ad5 E1 region from the 293 cells. This recombination event

presumably accounts for the frequent detection of wild-type adenovirus in preparations of recombinant virus and has been directly demonstrated to be the cause of wild-type contamination of the Ad2 based recombinant virus Ad2/CFTR-1 (Rich *et al.* (1993)).

Due to the high degree of sequence homology within the type C adenovirus subgroup such recombination is likely to occur if the vector is based on any group C adenovirus (types 1, 2, 5, 6).

In small scale production of recombinant adenoviruses, generation of contaminating wild-type virus can be managed by a screening process which discards those preparations of virus found to be contaminated. As the scale of virus production grows to meet expected demand for genetic therapeutics, the likelihood of any single lot being contaminated with a wild-type virus also will rise as well as the difficulty in providing non-contaminated recombinant preparations.

There will be over one million new cases of cancer diagnosed this year, and half that number of cancer-related deaths (American Cancer Society, 1993). p53 mutations are the most common genetic alteration associated with human cancers, occurring in 50-60% of human cancers (Hollstein *et al.* (1991); Bartek *et al.* (1991); Levine (1993)). The goal of gene therapy in treating p53 deficient tumors, for example, is to reinstate a normal, functional copy of the wild-type p53 gene so that control of cellular proliferation is restored. p53 plays a central role in cell cycle progression, arresting growth so that repair or apoptisis can occur in response to DNA damage. Wild-type p53 has recently been identified as a necessary component for apoptosis induced by irradiation or treatment with some chemotherapeutic agents (Lowe *et al.* (1993) A and B). Due to the high prevalence of p53 mutations in human

tumors, it is possible that tumors which have become refractory to chemotherapy and irradiation treatments may have become so due in part to the lack of wild-type p53. By resupplying functional p53 to these tumors, it is reasonable that they now are susceptible to apoptisis normally associated with the DNA damage induced by radiation and chemotherapy.

One of the critical points in successful human tumor suppressor gene therapy is the ability to affect a significant fraction of the cancer cells. The use of retroviral vectors has been largely explored for this purpose in a variety of tumor models. For example, for the treatment of hepatic malignancies, retroviral vectors have been employed with little success because these vectors are not able to achieve the high level of gene transfer required for *in vivo* gene therapy (Huber, B.E. et al., 1991; Caruso M. et al., 1993).

To achieve a more sustained source of virus production, researchers have attempted to overcome the problem associated with low level of gene transfer by direct injection of retroviral packaging cell lines into solid tumors (Caruso, M. et al., 1993; Ezzidine, Z.D. et al., 1991; Culver, K.W. et al., 1992). However, these methods are unsatisfactory for use in human patients because the method is troublesome and induces an inflammatory response against the packaging cell line in the patient. Another disadvantage of retroviral vectors is that they require dividing cells to efficiently integrate and express the recombinant gene of interest (Huber, B.E. 1991). Stable integration into an essential host gene can lead to the development or inheritance of pathogenic diseased states.

Recombinant adenoviruses have distinct advantages over retroviral and other gene delivery methods (for

review, see Siegfried (1993)). Adenoviruses have never been shown to induce tumors in humans and have been safely used as live vaccines (Straus (1984)). Replication deficient recombinant adenoviruses can be produced by replacing the E1 region necessary for replication with the target gene. Adenovirus does not integrate into the human genome as a normal consequence of infection, thereby greatly reducing the risk of insertional mutagenesis possible with retrovirus or adeno-associated viral (AAV) vectors. This lack of stable integration also leads to an additional safety feature in that the transferred gene effect will be transient, as the extrachromosomal DNA will be gradually lost with continued division of normal cells. Stable, high titer recombinant adenovirus can be produced at levels not achievable with retrovirus or AAV, allowing enough material to be produced to treat a large patient population. Moreover, adenovirus vectors are capable of highly efficient *in vivo* gene transfer into a broad range of tissue and tumor cell types. For example, others have shown that adenovirus mediated gene delivery has a strong potential for gene therapy for diseases such as cystic fibrosis (Rosenfeld *et al.* (1992); Rich *et al.* (1993)) and α_1-antitrypsin deficiency (Lemarchand *et al.* (1992)). Although other alternatives for gene delivery, such as cationic liposome/DNA complexes, are also currently being explored, none as yet appear as effective as adenovirus mediated gene delivery.

As with treating p53 deficient tumors, the goal of gene therapy for other tumors is to reinstate control of cellular proliferation. In the case of p53, introduction of a functional gene reinstates cell cycle control allowing for apoptotic cell death induced by therapeutic agents. Similarly, gene therapy is equally applicable to other tumor suppressor genes which can be used either alone or in combination with therapeutic agents to control cell cycle progression of tumor cells and/or induce cell death.

Moreover, genes which do not encode cell cycle regulatory proteins, but directly induce cell death such as suicide genes or, genes which are directly toxic to the cell can be used in gene therapy protocols to directly eliminate the cell cycle progression of tumor cells.

Regardless of which gene is used to reinstate the control of cell cycle progression, the rationale and practical applicability of this approach is identical. Namely, to achieve high efficiencies of gene transfer to express therapeutic quantities of the recombinant product. The choice of which vector to use to enable high efficiency gene transfer with minimal risk to the patient is therefore important to the level of success of the gene therapy treatment.

Thus, there exists a need for vectors and methods which provide high level gene transfer efficiencies and protein expression which provide safe and effective gene therapy treatments. The present invention satisfies this need and provides related advantages as well.

SUMMARY OF THE INVENTION

This invention provides a recombinant adenovirus expression vector characterized by the partial or total deletion of the adenoviral protein IX DNA and having a gene encoding a foreign protein or a functional fragment or mutant thereof. Transformed host cells and a method of producing recombinant proteins and gene therapy also are included within the scope of this invention.

Thus, for example, the adenoviral vector of this invention can contain a foreign gene for the expression of a protein effective in regulating the cell cycle, such as p53, Rb, or mitosin, or in inducing cell death, such as the conditional suicide gene thymidine kinase. (The latter

must be used in conjunction with a thymidine kinase metabolite in order to be effective).

BRIEF DESCRIPTION OF THE FIGURES

Figure 1 shows a recombinant adenoviral vector of this invention. This construct was assembled as shown in Figure 1. The resultant virus bears a 5' deletion of adenoviral sequences extending from nucleotide 356 to 4020 and eliminates the E1a and E1b genes as well as the entire protein IX coding sequence, leaving the polyadenylation site shared by the E1b and pIX genes intact for use in terminating transcription of any desired gene.

Figure 2 shows the amino acid sequence of $p110^{RB}$.

Figure 3 shows a DNA sequence encoding a retinoblastoma tumor suppressor protein.

Figure 4 shows schematic of recombinant p53/adenovirus constructs within the scope of this invention. The p53 recombinants are based on Ad 5 and have had the E1 region of nucleotides 360-3325 replaced with a 1.4 kb full length p53 cDNA driven by the Ad 2 MLP (A/M/53) or human CMV (A/C/53) promoters followed by the Ad 2 tripartite leader cDNA. The control virus A/M has the same Ad 5 deletions as the A/M/53 virus but lacks the 1.4 kb p53 cDNA insert. The remaining E1b sequence (705 nucleotides) have been deleted to create the protein IX deleted constructs A/M/N/53 and A/C/N/53. These constructs also have a 1.9 kb Xba I deletion within adenovirus type 5 region E3.

Figures 5A and 5B show p53 protein expression in tumor cells infected with A/M/53 and A/C/53. Figure 5A) Saos-2 (osteosarcoma) cells were infected at the indicated multiplicities of infection (MOI) with either the A/M/53 or

A/C/53 purified virus and harvested 24 hours later. The p53 antibody pAb 1801 was used to stain immunoblots of samples loaded at equal total protein concentrations. Equal protein concentration of SW480 cell extracts, which overexpress mutant p53 protein, were used as a marker for p53 size. "O" under the A/C/53 heading indicates a mock infection, containing untreated Saos-2 lysate. Figure 5B) Hep 3B (hepatocellular carcinoma) cells were infected with the A/M/53 or A/C/53 virus at the indicated MOI and analyzed as in part A.) The arrow indicates the position of the p53 protein.

Figures 6A through 6C show p53 dependent Saos-2 morphology change. Subconfluent (1×10^5 cells/10 cm plate) Saos-2 cells were either uninfected (A), infected at an MOI = 50 with (B) the control A/M virus or (C) the A/C/53 virus. The cells were photographed 72 hours post-infection.

Figure 7 shows p53 dependent inhibition of DNA synthesis in human tumor cell lines by A/M/N/53 and A/C/N/53. Nine different tumor cell lines were infected with either control adenovirus A/M (-x-x-), or the p53 expressing A/M/N/53 (-Δ-Δ-), or A/C/N/53 (-O-O-) virus at increasing MOI as indicated. The tumor type and p53 status is noted for each cell line (wt = wild type, null = no protein expressed, mut = mutant protein expressed). DNA synthesis was measured 72 hours post-infection as described below in Experiment No. II. Results are from triplicate measurements at each dose (mean+/- SD), and are plotted as % of media control versus MOI. * H69 cells were only tested with A/M and A/M/N/53 virus.

Figure 8 shows tumorigenicity of p53 infected Saos-2 cells in nude mice. Saos-2 cells were infected with either the control A/M virus or the p53 recombinant A/M/N/53 at MOI = 30. Treated cells were injected

subcutaneously into the flanks of nude mice, and tumor dimensions were measured (as described in Experiment No. II) twice per week for 8 weeks. Results are plotted as tumor size versus days post tumor cell implantation for both control A/M (-x-x-) and A/M/N/53 (-Δ-Δ-) treated cells. Error bars represent the mean tumor size =/- SEM for each group of 4 animals at each time point.

Figure 9 is expression of rAd/p53 RNA in established tumors. H69 (SCLC) cells were injected subcutaneously into nude mice and allowed to develop tumors for 32 days until reaching a size of approximately 25-50 mm^3. Mice were randomized and injected peritumorally with 2 x 10^9 pfu of either control A/C/ß-gal or A/C/53 virus. Tumors were excised 2 and 7 days post injection, and polyA RNA was prepared from each tumor sample. RT-PCR was carried out using equal RNA concentrations and primers specific for recombinant p53 message. PCR amplification was for 30 cycles at 94°C 1 min., 55°C 1.5 min., 72°C 2 min., and a 10 min., 72°C final extension period in an Omnigen thermalcycler (Hybaid). The PCR primers used were a 5' Tripartite Leader cDNA (5' - CGCCACCGAGGGACCTGAGCGAGTC-3') and a 3' p53 primer (5' - TTCTGGGAAGGGACAGAAGA-3'). Lanes 1, 2, 4, and 5 are p53 treated samples excised at day 2 or 7 as indicated. Lanes 3 and 6 are from ß-gal treated tumors. Lanes 7,8, and 9 are replicates of lanes 4,5, and 6 respectively, amplified with actin primers to verify equal loading. Lane 10 is a positive control using a tripartite/p53 containing plasmid.

Figures 10A and 10B show *in vivo* tumor suppression and increased survival time with A/M/N/53. H69 (SCLC) tumor cells were injected subcutaneously into nude mice and allowed to develop for 2 weeks. Peritumoral injections of either buffer alone (---), control A/M adenovirus (-x-x-), or A/M/N/53 (-Δ-Δ), both viruses (2 x 10^9 pfu/injection) were administered twice per week for a

total of 8 doses. Tumor dimensions were measured twice per week and tumor volume was estimated as described in Experiment No. II. A) Tumor size is plotted for each virus versus time (days) post inoculation of H69 cells. Error bars indicate the mean tumor size +/- SEM for each group of 5 animals. Arrows indicate days virus injections. B) Mice were monitored for survival and the fraction of mice surviving per group versus time post inoculation of buffer alone (----), control A/M (··· ··· ···) or A/M/N/53 (——) virus treated H69 cells is plotted.

Figures 11A through 11C show maps of recombinant plasmid constructions. Plasmids were constructed as detailed in below. Bold lines in the constructs indicate genes of interest while boldface type indicates the restriction sites used to generate the fragments to be ligated together to form the subsequent plasmid as indicated by the arrows. In Figure 11A, the plasmid pACNTK was constructed by subcloning the HSV-TK gene from pMLBKTK (ATCC No. 39369) into the polylinker of a cloning vector, followed by isolation of the TK gene with the desired ends for cloning into the pACN vector. The pACN vector contains adenoviral sequences necessary for *in vivo* recombination to occur to form recombinant adenovirus (see Figure 12). In Figure 11B, the construction of the plasmid pAANTK is shown beginning with PCR amplified fragments encoding the α-fetoprotein enhancer (AFP-E) and promoter (AFP-P) regions subcloned through several steps into a final plasmid where the AFP enhancer and promoter are upstream of the HSV-TK gene followed by adenovirus Type 2 sequences necessary for *in vivo* recombination to occur to form recombinant adenovirus. In Figure 11C, the construction of the plasmid pAANCAT is shown beginning with the isolation of the chloramphenicol acetyltransferase (CAT) gene from a commercially available plasmid and subcloning it into the pAAN plasmid (see above), generating the final plasmid pAANCAT where the AFP enhancer/promoter direct

transcription of the CAT gene in an adenovirus sequence background.

Figure 12 is a schematic map of recombinant adenoviruses ACNTK, AANTK and AANCAT. To construct recombinant adenoviruses from the plasmids described in Figure 11, 4 parts (20 μg) of either plasmid pACNTK, pAANTK, or pAANCAT were linearized with Eco R1 and cotransfected with 1 part (5 μg) of the large fragment of Cla 1 digested recombinant adenovirus (rACß-gal) containing an E3 region deletion (Wills et al., 1994). In the resulting viruses, the Ad 5 nucleotides 360 - 4021 are replaced by either the CMV promoter and tripartite leader cDNA (TPL) or the α-fetoprotein enhancer and promoter (AFP) driving expression of the HSV-1 TK or CAT gene as indicated. The resulting recombinant adenoviruses are designated ACNTK, AANTK, and AANCAT respectively.

Figure 13 shows promoter specificity of CAT expression in the recombinant adenoviral vectors. Two (2) X 10^6 of the designated cell lines were infected at MOIs = 30 or 100 of the recombinant adenovirus AANCAT as indicated or left uninfected (UN). Hep G2 and Hep 3B cells express α-fetoprotein whereas the other cell lines do not. After three days, the cells were harvested, extract volumes were adjusted for equal total protein concentrations, and CAT activity was measured as described in Methods section, below. An equal number of uninfected cells served as individual controls for background CAT activity, while ^{14}C labelled chloramphenicol (^{14}C-only) and extract from a stable cell line (B21) expressing CAT activity served as negative and positive controls respectively. Percent conversion of acetyl CoA is indicated, demonstrating that CAT expression is limited to those cells expressing α-fetoprotein.

Figure 14 shows the effects of TK/GCV treatment on hepatocellular carcinoma cell lines and the effects of promoter specificity. Hep-G2 (AFP positive) and HLF (AFP negative) cell lines were infected overnight with ACNTK [-Δ-] AANTK [-▲-], or control ACN [-□-] virus at an infection multiplicity of 30 and subsequently treated with a single dose of ganciclovir at the indicated concentrations. Cell proliferation was assessed by adding ^{3}H-thymidine to the cells approximately 18 hours prior to harvest. ^{3}H-thymidine incorporation into cellular nucleic acid was measured 72 hours after infection (Top Count, Packard and expressed as a percent (mean +/- S.D.) of untreated control. The results show a non-selective dose dependent inhibition of proliferation with the CMV driven construct, while AFP driven TK selectively inhibits Hep-G2.

Figure 15 shows cytotoxicity of ACNTK plus ganciclovir in HCC. HLF cells were infected at an MOI of 30 with either ACNTK [-●-] or the control virus ACN [-□-] and treated with ganciclovir at the indicated doses. Seventy-two (72) hours after ganciclovir treatment, the amount of lactate dehydrogenase (LDH) released into the cell supernatant were measured colorimetrically and plotted (mean+/-SEM) versus ganciclovir concentration for the two virus treated groups.

Figures 16A and 16B show the effect of ACNTK plus ganciclovir on established hepatocellular carcinoma (HCC) tumors in nude mice. One (1) X 10^{7} Hep 3B cells were injected subcutaneously into the flank of female nude mice and allowed to grow for 27 days. Mice then received intratumoral and peritumoral injections of either the ACNTK [-●-] or control ACN [-□-] virus (1 X 10^{9} iu in 100 μl volume) every other day for a total of three doses (indicated by arrows). Injections of ganciclovir (100 mg/kg ip) began 24 hours after the initial virus dose and continued for a total of 10 days. In Figure 6A, tumor

sizes are plotted for each virus versus days post infection (mean +/- SEM). In Figure 6B, body weight for each virus-treated animal group is plotted as the mean +/-SEM versus days post infection.

DETAILED DESCRIPTION OF THE INVENTION

To reduce the frequency of contamination with wild-type adenovirus, it is desirable to improve either the virus or the cell line to reduce the probability of recombination. For example, an adenovirus from a group with low homology to the group C viruses could be used to engineer recombinant viruses with little propensity for recombination with the Ad5 sequences in 293 cells. However, an alternative, easier means of reducing the recombination between viral and cellular sequences is to increase the size of the deletion in the recombinant virus and thereby reduce the extent of shared sequence between it and the Ad5 genes in the 293 cells.

Deletions which extend past 3.5 kb from the 5' end of the adenoviral genome affect the gene for adenoviral protein IX and have not been considered desirable in adenoviral vectors (see below).

The protein IX gene of the adenoviruses encodes a minor component of the outer adenoviral capsid which stabilizes the group-of-nine hexons which compose the majority of the viral capsid (Stewart (1993)). Based upon study of adenovirus deletion mutants, protein IX initially was thought to be a non-essential component of the adenovirus, although its absence was associated with greater heat lability than observed with wild-type virus (Colby and Shenk (1981)). More recently it was discovered that protein IX is essential for packaging full length viral DNA into capsids and that in the absence of protein IX, only genomes at least 1 kb smaller than wild-type could

be propagated as recombinant viruses (Ghosh-Choudhury *et al.* (1987)). Given this packaging limitation, protein IX deletions deliberately have not been considered in the design of adenoviral vectors.

In this application, reference is made to standard textbooks of molecular biology that contain definitions, methods and means for carrying out basic techniques, encompassed by the present invention. See for example, Sambrook et al. (1989) and the various references cited therein. This reference and the cited publications are expressly incorporated by reference into this disclosure.

Contrary to what has been known in the art, this invention claims the use of recombinant adenoviruses bearing deletions of the protein IX gene as a means of reducing the risk of wild-type adenovirus contamination in virus preparations for use in diagnostic and therapeutic applications such as gene therapy. As used herein, the term "recombinant" is intended to mean a progeny formed as the result of genetic engineering. These deletions can remove an additional 500 to 700 base pairs of DNA sequence that is present in conventional E1 deleted viruses (smaller, less desirable, deletions of portions of the pIX gene are possible and are included within the scope of this invention) and is available for recombination with the Ad5 sequences integrated in 293 cells. Recombinant adenoviruses based on any group C virus, serotype 1, 2, 5 and 6, are included in this invention. Also encompassed by this invention is a hybrid Ad2/Ad5 based recombinant virus expressing the human p53 cDNA from the adenovirus type 2 major late promoter. This construct was assembled as shown in Figure 1. The resultant virus bears a 5' deletion of adenoviral sequences extending from about nucleotide 357 to 4020 and eliminates the E1a and E1b genes as well as the entire protein IX coding sequence, leaving the

polyadenylation site shared by the E1b and protein IX genes intact for use in terminating transcription of any desired gene. A separate embodiment is shown in Figure 4. Alternatively, the deletion can be extended an additional 30 to 40 base pairs without affecting the adjacent gene for protein IVa2, although in that case an exogenous polyadenylation signal is provided to terminate transcription of genes inserted into the recombinant virus. The initial virus constructed with this deletion is easily propagated in 293 cells with no evidence of wild-type viral contamination and directs robust p53 expression from the transcriptional unit inserted at the site of the deletion.

The insert capacity of recombinant viruses bearing the protein IX deletion described above is approximately 2.6 kb. This is sufficient for many genes including the p53 cDNA. Insert capacity can be increased by introducing other deletions into the adenoviral backbone, for example, deletions within early regions 3 or 4 (for review see: Graham and Prevec (1991)). For example, the use of an adenoviral backbone containing a 1.9 kb deletion of non-essential sequence within early region 3. With this additional deletion, the insert capacity of the vector is increased to approximately 4.5 kb, large enough for many larger cDNAs, including that of the retinoblastoma tumor suppressor gene.

A recombinant adenovirus expression vector characterized by the partial or total deletion of the adenoviral protein IX DNA and having a gene encoding a foreign protein, or a functional fragment or mutant thereof is provided by this invention. These vectors are useful for the safe recombinant production of diagnostic and therapeutic polypeptides and proteins, and more importantly, for the introduction of genes in gene therapy. Thus, for example, the adenoviral vector of this invention can contain a foreign gene for the expression of a protein

effective in regulating the cell cycle, such as p53, Rb, or mitosin, or in inducing cell death, such as the conditional suicide gene thymidine kinase. (The latter must be used in conjunction with a thymidine kinase metabolite in order to be effective).Any expression cassette can be used in the vectors of this invention. An "expression cassette" means a DNA molecule having a transcription promoter/enhancer such as the CMV promotor enhancer, etc., a foreign gene, and in some embodiments defined below, a polyadentlyation signal. As used herein, the term "foreign gene" is intended to mean a DNA molecule not present in the exact orientation and position as the counterpart DNA molecule found in wild-type adenovirus. The foreign gene is a DNA molecule up to 4.5 kilobases. "Expression vector" means a vector that results in the expression of inserted DNA sequences when propagated in a suitable host cell, i.e., the protein or polypeptide coded for by the DNA is synthesized by the host's system. The recombinant adenovirus expression vector can contain part of the gene encoding adenovirus protein IX, provided that biologically active protein IX or fragment thereof is not produced. Example of this vector are an expression vector having the restriction enzyme map of Figures 1 or 4.

Inducible promoters also can be used in the adenoviral vector of this invention. These promoters will initiate transcription only in the presence of an additional molecule. Examples of inducible promoters include those obtainable from a ß-interferon gene, a heat shock gene, a metallothionine gene or those obtainable from steroid hormone-responsive genes. Tissue specific expression has been well characterized in the field of gene expression and tissue specific and inducible promoters such as these are very well known in the art. These genes are used to regulate the expression of the foreign gene after it has been introduced into the target cell.

Also provided by this invention is a recombinant adenovirus expression vector, as described above, having less extensive deletions of the protein IX gene sequence extending from 3500 bp from the 5′ viral termini to approximately 4000 bp, in one embodiment. In a separate embodiment, the recombinant adenovirus expression vector can have a further deletion of a non-essential DNA sequence in adenovirus early region 3 and/or 4 and/or deletion of the DNA sequences designated adenovirus E1a and E1b. In this embodiment, foreign gene is a DNA molecule of a size up to 4.5 kilobases.

A further embodiment has a deletion of up to forty nucleotides positioned 3′ to the E1a and E1b deletion and pIX and a foreign DNA molecule encoding a polyadenylation signal inserted into the recombinant vector in a position relative to the foreign gene to regulate the expression of the foreign gene.

For the purposes of this invention, the recombinant adenovirus expression vector can be derived from wild-type group adenovirus, serotype 1, 2, 5 or 6.

In one embodiment, the recombinant adenovirus expression vector has a foreign gene coding for a functional tumor suppressor protein, or a biologically active fragment thereof. As used herein, the term "functional" as it relates to a tumor suppressor gene, refers to tumor suppressor genes that encode tumor suppressor proteins that effectively inhibit a cell from behaving as a tumor cell. Functional genes can include, for instance, wild type of normal genes and modifications of normal genes that retains its ability to encode effective tumor suppressor proteins and other anti-tumor genes such as a conditional suicide protein or a toxin.

Similarly, "non-functional" as used herein is synonymous with "inactivated." Non-functional or defective genes can be caused by a variety of events, including for example point mutations, deletions, methylation and others known to those skilled in the art.

As used herein, an "active fragment" of a gene includes smaller portions of the gene that retain the ability to encode proteins having tumor suppressing activity. $p56^{RB}$, described more fully below, is but one example of an active fragment of a functional tumor suppressor gene. Modifications of tumor suppressor genes are also contemplated within the meaning of an active fragment, such as additions, deletions or substitutions, as long as the functional activity of the unmodified gene is retained.

Another example of a tumor suppressor gene is retinoblastoma (RB). The complete RB cDNA nucleotide sequences and predicted amino acid sequences of the resulting RB protein (designated $p110^{RB}$) are shown in Lee *et al.* (1987) and in Figure 3. Also useful to express retinoblastoma tumor suppressor protein is a DNA molecule encoding the amino acid sequence shown in Figure 2 or having the DNA sequence shown in Figure 3. A truncated version of $p110^{RB}$, called $p56^{RB}$ also is useful. For the sequence of $p56^{RB}$, see Huang *et al.* (1991). Additional tumor suppressor genes can be used in the vectors of this invention. For illustration purposes only, these can be p16 protein (Kamb *et al.* (1994)), p21 protein, Wilm's tumor WT1 protein, mitosin, h-NUC, or colon carcinoma DCC protein. Mitosin is described in X. Zhu and W-H Lee, U.S. Application Serial No. 08/141,239, filed October 22, 1993, and a subsequent continuation-in-part by the same inventors, attorney docket number P-CJ 1191, filed October 24, 1994, both of which are herein incorporated by reference. Similarly, h-NUC is described by W-H Lee and P-

L Chen, U.S. Application Serial No. 08/170,586, filed December 20, 1993, herein incorporated by reference.

As is known to those of skill in the art, the term "protein" means a linear polymer of amino acids joined in a specific sequence by peptide bonds. As used herein, the term "amino acid" refers to either the D or L stereoisomer form of the amino acid, unless otherwise specifically designated. Also encompassed within the scope of this invention are equivalent proteins or equivalent peptides, e.g., having the biological activity of purified wild type tumor suppressor protein. "Equivalent proteins" and "equivalent polypeptides" refer to compounds that depart from the linear sequence of the naturally occurring proteins or polypeptides, but which have amino acid substitutions that do not change its biologically activity. These equivalents can differ from the native sequences by the replacement of one or more amino acids with related amino acids, for example, similarly charged amino acids, or the substitution or modification of side chains or functional groups.

Also encompassed within the definition of a functional tumor suppressor protein is any protein whose presence reduces the tumorigenicity, malignancy or hyperproliferative phenotype of the host cell. Examples of tumor suppressor proteins within this definition include, but are not limited to $p110^{RB}$, $p56^{RB}$, mitosin, h-NUC and p53. "Tumorigenicity" is intended to mean having the ability to form tumors or capable of causing tumor formation and is synonymous with neoplastic growth. "Malignancy" is intended to describe a tumorigenic cell having the ability to metastasize and endanger the life of the host organism. "Hyperproliferative phenotype" is intended to describe a cell growing and dividing at a rate beyond the normal limitations of growth for that cell type. "Neoplastic" also is intended to include cells lacking endogenous

functional tumor suppressor protein or the inability of the cell to express endogenous nucleic acid encoding a functional tumor suppressor protein.

An example of a vector of this invention is a recombinant adenovirus expression vector having a foreign gene coding for p53 protein or an active fragment thereof is provided by this invention. The coding sequence of the p53 gene is set forth below in Table I.

TABLE 1

```
                                                                  50
V*SHR PGSR* LLGSG DTLRS GWERA FHDGD TLPWI GSQTA FRVTA MEEPQ
                                                                 100
SDPSV EPPLS QETFS DLWKL LPENN VLSPL PSQAM DDLML SPDDI EQWFT
                                                                 150
EDPGP DEAPR MPEAA PPVAP APAAP TPAAP APAPS WPLSS SVPSQ KTYQG
                                                                 200
SYGFR LGFLH SGTAK SVTCT YSPAL NKMFC QLAKT CPVQL WVDST PPPGT
                                                                 250
RVRAM AIYKQ SQHMT EVVRR CPHHE RCSDS DGLAP PQHLI RVEGN LRVEY
                                                                 300
LDDRN TFRHS VVVPY EPPEV GSDCT TIHYN YMCNS SCMGG MNRRP ILTII
                                                                 350
TLEDS SGNLL GRNSF EVRVC ACPGR DRRTE EENLR KKGEP HHELP PGSTK
                                                                 400
RALPN NTSSS PQPKK KPLDG EYFTL QIRGR ERFEM FRELN EALEL KDAQA

GKEPG GSRAH SSHLK SKKGQ STSRH KKLMF KTEGP DSD*
* = Stop codon
```

Any of the expression vectors described herein are useful as compositions for diagnosis or therapy. The vectors can be used for screening which of many tumor suppressor genes would be useful in gene therapy. For example, a sample of cells suspected of being neoplastic can be removed from a subject and mammal. The cells can then be contacted, under suitable conditions and with an effective amount of a recombinant vector of this invention having inserted therein a foreign gene encoding one of several functional tumor suppressor genes. Whether the introduction of this gene will reverse the malignant phenotype can be measured by colony formation in soft agar or tumor formation in nude mice. If the malignant phenotype is reversed, then that foreign gene is determined to be a positive candidate for successful gene therapy for the subject or mammal. When used pharmaceutically, they

can be combined with one or more pharmaceutically acceptable carriers. Pharmaceutically acceptable carriers are well known in the art and include aqueous solutions such as physiologically buffered saline or other solvents or vehicles such as glycols, glycerol, vegetable oils (eg., olive oil) or injectable organic esters. A pharmaceutically acceptable carrier can be used to administer the instant compositions to a cell *in vitro* or to a subject *in vivo*.

A pharmaceutically acceptable carrier can contain a physiologically acceptable compound that acts, for example, to stabilize the composition or to increase or decrease the absorption of the agent. A physiologically acceptable compound can include, for example, carbohydrates, such as glucose, sucrose or dextrans, antioxidants, such as ascorbic acid or glutathione, chelating agents, low molecular weight proteins or other stabilizers or excipients. Other physiologically acceptable compounds include wetting agents, emulsifying agents, dispersing agents or preservatives, which are particularly useful for preventing the growth or action of microorganisms. Various preservatives are well known and include, for example, phenol and ascorbic acid. One skilled in the art would know that the choice of a pharmaceutically acceptable carrier, including a physiologically acceptable compound, depends, for example, on the route of administration of the polypeptide and on the particular physio-chemical characteristics of the specific polypeptide. For example, a physiologically acceptable compound such as aluminum monosterate or gelatin is particularly useful as a delaying agent, which prolongs the rate of absorption of a pharmaceutical composition administered to a subject. Further examples of carriers, stabilizers or adjutants can be found in Martin, Remington's Pharm. Sci., 15th Ed. (Mack Publ. Co., Easton, 1975), incorporated herein by reference. The

pharmaceutical composition also can be incorporated, if desired, into liposomes, microspheres or other polymer matrices (Gregoriadis, Liposome Technology, Vol. 1 (CRC Press, Boca Raton, Florida 1984), which is incorporated herein by reference). Liposomes, for example, which consist of phospholipids or other lipids, are nontoxic, physiologically acceptable and metabolizable carriers that are relatively simple to make and administer.

As used herein, "pharmaceutical composition" refers to any of the compositions of matte described herein in combination with one or more of the above pharmaceutically acceptable carriers. The compositions can then be administered therapeutically or prophylactically. They can be contacted with the host cell *in vivo*, *ex vivo*, or *in vitro*, in an effective amount. *In vitro* and *ex vivo* means of contacting host cells are provided below. When practiced *in vivo*, methods of administering a pharmaceutical containing the vector of this invention, are well known in the art and include but are not limited to, administration orally, intra-tumorally, intravenously, intramuscularly or intraperitoneal. Administration can be effected continuously or intermittently and will vary with the subject and the condition to be treated, e.g., as is the case with other therapeutic compositions (Landmann *et al.* (1992); Aulitzky *et al.* (1991); Lantz *et al.* (1990); Supersaxo *et al.* (1988); Demetri *et al.* (1989); and LeMaistre *et al.* (1991)).

Further provided by this invention is a transformed procaryotic or eucaryotic host cell, for example an animal cell or mammalian cell, having inserted a recombinant adenovirus expression vector described above. Suitable procaryotic cells include but are not limited to bacterial cells such as *E. coli* cells. Methods of transforming host cells with retroviral vectors are known in the art, see Sambrook et al. (1989) and include, but are

not limited to transfection, electroporation, and microinjection.

As used throughout this application, the term animal is intended to be synonymous with mammal and is to include, but not be limited to bovine, porcine, feline, simian, canine, equine, murine, rat or human. Additional host cells include but are not limited to any neoplastic or tumor cell, such as osteosarcoma, ovarian carcinoma, breast carcinoma, melanoma, hepatocarcinoma, lung cancer, brain cancer, colorectal cancer, hematopoietic cell, prostate cancer, cervical carcinoma, retinoblastoma, esophageal carcinoma, bladder cancer, neuroblastoma, or renal cancer.

Additionally, any eucaryotic cell line capable of expressing E1a and E1b or E1a, E1b and pIX is a suitable host for this vector. In one embodiment, a suitable eucaryotic host cell is the 293 cell line available from the American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland, U.S.A. 20231.

Any of the transformed host cells described herein are useful as compositions for diagnosis or therapy. When used pharmaceutically, they can be combined with various pharmaceutically acceptable carriers. Suitable pharmaceutically acceptable carriers are well known to those of skill in the art and, for example, are described above. The compositions can then be administered therapeutically or prophylactically, in effective amounts, described in more detail below.

A method of transforming a host cell also is provided by this invention. This method provides contacting a host cell, i.e., a procaryotic or eucaryotic host cell, with any of the expression vectors described herein and under suitable conditions. Host cells transformed by this method also are claimed within the

scope of this invention. The contacting can be effected *in vitro, in vivo, or ex vivo*, using methods well known in the art (Sambrook et al. (1989)) and using effective amounts of the expression vectors. Also provided in this invention is a method of producing a recombinant protein or polypeptide by growing the transformed host cell under suitable conditions favoring the transcription and translation of the inserted foreign gene. Methods of recombinant expression in a variety of host cells, such as mammalian, yeast, insect or bacterial cells, are widely known, including those described in Sambrook et al., supra. The translated foreign gene can then be isolated by convention means, such as column purification or purification using an anti-protein antibody. The isolated protein or polypeptide also is intended within the scope of this invention. As used herein, purified or isolated mean substantially free of native proteins or nucleic acids normally associated with the protein or polypeptide in the native or host cell environment.

Also provided by this invention are non-human animals having inserted therein the expression vectors or transformed host cells of this invention. These "transgenic" animals are made using methods well known to those of skill in the art, for example as described in U.S. Patent No. 5,175,384 or by conventional *ex vivo* therapy techniques, as described in Culver et al. (1991).

As shown in detail below, the recombinant adenoviruses expressing a tumor suppressor wild-type p53, as described above, can efficiently inhibit DNA synthesis and suppress the growth of a broad range of human tumor cell types, including clinical targets. Furthermore, recombinant adenoviruses can express tumor suppression genes such as p53 in an *in vivo* established tumor without relying on direct injection into the tumor or prior *ex vivo* treatment of the cancer cells. The p53 expressed is

functional and effectively suppresses tumor growth *in vivo* and significantly increases survival time in a nude mouse model of human lung cancer.

Thus, the vectors of this invention are particularly suited for gene therapy. Accordingly, methods of gene therapy utilizing these vectors are within the scope of this invention. The vector is purified and then an effective amount is administered *in vivo* or *ex vivo* into the subject. Methods of gene therapy are well known in the art, see, for example, Larrick, J.W. and Burck, K.L. (1991) and Kreigler, M. (1990). "Subject" means any animal, mammal, rat, murine, bovine, porcine, equine, canine, feline or human patient. When the foreign gene codes for a tumor suppressor gene or other anti-tumor protein, the vector is useful to treat or reduce hyperproliferative cells in a subject, to inhibit tumor proliferation in a subject or to ameliorate a particular related pathology. Pathologic hyperproliferative cells are characteristic of the following disease states, thyroid hyperplasia - Grave's Disease, psoriasis, benign prostatic hypertrophy, Li-Fraumeni syndrome including breast cancer, sarcomas and other neoplasms, bladder cancer, colon cancer, lung cancer, various leukemias and lymphomas. Examples of non-pathologic hyperproliferative cells are found, for instance, in mammary ductal epithelial cells during development of lactation and also in cells associated with wound repair. Pathologic hyperproliferative cells characteristically exhibit loss of contact inhibition and a decline in their ability to selectively adhere which implies a change in the surface properties of the cell and a further breakdown in intercellular communication. These changes include stimulation to divide and the ability to secrete proteolytic enzymes.

Moreover, the present invention relates to a method for depleting a suitable sample of pathologic

mammalian hyperproliferative cells contaminating hematopoietic precursors during bone marrow reconstitution via the introduction of a wild type tumor suppressor gene into the cell preparation using the vector of this invention (whether derived from autologous peripheral blood or bone marrow). As used herein, a "suitable sample" is defined as a heterogeneous cell preparation obtained from a patient, e.g., a mixed population of cells containing both phenotypically normal and pathogenic cells. "Administer" includes, but is not limited to introducing into the cell or subject intravenously, by direct injection into the tumor, by intra-tumoral injection, by intraperitoneal administration, by aerosol administration to the lung or topically. Such administration can be combined with a pharmaceutically-accepted carrier, described above.

The term "reduced tumorigenicity" is intended to mean tumor cells that have been converted into less tumorigenic or non-tumorigenic cells. Cells with reduced tumorigenicity either form no tumors *in vivo* or have an extended lag time of weeks to months before the appearance of *in vivo* tumor growth and/or slower growing three dimensional tumor mass compared to tumors having fully inactivated or non-functional tumor suppressor gene.

As used herein, the term "effective amount" is intended to mean the amount of vector or anti-cancer protein which achieves a positive outcome on controlling cell proliferation. For example, one dose contains from about 10^8 to about 10^{13} infectious units. A typical course of treatment would be one such dose a day over a period of five days. An effective amount will vary on the pathology or condition to be treated, by the patient and his status, and other factors well known to those of skill in the art. Effective amounts are easily determined by those of skill in the art.

Also within the scope of this invention is a method of ameliorating a pathology characterized by hyperproliferative cells or genetic defect in a subject by administering to the subject an effective amount of a vector described above containing a foreign gene encoding a gene product having the ability to ameliorate the pathology, under suitable conditions. As used herein, the term "genetic defect" means any disease or abnormality that results from inherited factors, such as sickle cell anemia or Tay-Sachs disease.

This invention also provides a method for reducing the proliferation of tumor cells in a subject by introducing into the tumor mass an effective amount of an adenoviral expression vector containing an anti-tumor gene other than a tumor suppressor gene. The anti-tumor gene can encode, for example, thymidine kinase (TK). The subject is then administered an effective amount of a therapeutic agent, which in the presence of the anti-tumor gene is toxic to the cell. In the specific case of thymidine kinase, the therapeutic agent is a thymidine kinase metabolite such as ganciclovir (GCV), 6-methoxypurine arabinonucleoside (araM), or a functional equivalent thereof. Both the thymidine kinase gene and the thymidine kinase metabolite must be used concurrently to be toxic to the host cell. However, in its presence, GCV is phosphorylated and becomes a potent inhibitor of DNA synthesis whereas araM gets converted to the cytotoxic anabolite araATP. Other anti-tumor genes can be used as well in combination with the corresponding therapeutic agent to reduce the proliferation of tumor cells. Such other gene and therapeutic agent combinations are known by one skilled in the art. Another example would be the vector of this invention expressing the enzyme cytosine deaminase. Such vector would be used in conjunction with administration of the drug 5-fluorouracil (Austin and Huber, 1993), or the recently described E. Coli Deo Δ gene

in combination with 6-methyl-purine-2'-deosribonucleoside (Sorscher et al 1994).

As with the use of the tumor suppressor genes described previously, the use of other anti-tumor genes, either alone or in combination with the appropriate therapeutic agent provides a treatment for the uncontrolled cell growth or proliferation characteristic of tumors and malignancies. Thus, this invention provides a therapy to stop the uncontrolled cellular growth in the patient thereby alleviating the symptoms of the disease or cachexia present in the patient. The effect of this treatment includes, but is not limited to, prolonged survival time of the patient, reduction in tumor mass or burden, apoptosis of tumor cells or the reduction of the number of circulating tumor cells. Means of quantifying the beneficial effects of this therapy are well known to those of skill in the art.

The invention provides a recombinant adenovirus expression vector characterized by the partial or total deletion of the adenoviral protein IX DNA and having a foreign gene encoding a foreign protein, wherein the foreign protein is a suicide gene or functional equivalent thereof. The anti-cancer gene TK, described above, is an example of a suicide gene because when expressed, the gene product is, or can be made to be lethal to the cell. For TK, lethality is induced in the presence of GCV. The TK gene is derived from herpes simplex virus by methods well known to those of skill in the art. The plasmid pMLBKTK in E. coli HB101 (from ATCC #39369) is a source of the herpes simplex virus (HSV-1) thymidine kinase (TK) gene for use in this invention. However, many other sources exist as well.

The TK gene can be introduced into the tumor mass by combining the adenoviral expression vector with a

suitable pharmaceutically acceptable carrier. Introduction can be accomplished by, for example, direct injection of the recombinant adenovirus into the tumor mass. For the specific case of a cancer such as hepatocellular carcinoma (HCC), direct injection into the hepatic artery can be used for delivery because most HCCs derive their circulation from this artery. To control proliferation of the tumor, cell death is induced by treating the patients with a TK metabolite such as ganciclovir to achieve reduction of tumor mass. The TK metabolite can be administered, for example, systemically, by local innoculation into the tumor or in the specific case of HCC, by injection into the hepatic artery. The TK metabolite is preferably administered at least once daily but can be increased or decreased according to the need. The TK metabolite can be administered simultaneous or subsequent to the administration of the TK containing vector. Those skilled in the art know or can determine the dose and duration which is therapeutically effective.

A method of tumor-specific delivery of a tumor suppressor gene is accomplished by contacting target tissue in an animal with an effective amount of the recombinant adenoviral expression vector of this invention. The gene is intended to code for an anti-tumor agent, such as a functional tumor suppressor gene or suicide gene. "Contacting" is intended to encompass any delivery method for the efficient transfer of the vector, such as intra-tumoral injection.

The use of the adenoviral vector of this invention to prepare medicaments for the treatment of a disease or for therapy is further provided by this invention.

The following examples are intended to illustrate, not limit the scope of this invention.

EXPERIMENT NO. I

Plasmid pAd/MLP/p53/E1b- was used as the starting material for these manipulations. This plasmid is based on the pBR322 derivative pML2 (pBR322 deleted for base pairs 1140 to 2490) and contains adenovirus type 5 sequences extending from base pair 1 to base pair 5788 except that it is deleted for adenovirus type 5 base pairs 357 to 3327. At the site of the Ad5 357/3327 deletion a transcriptional unit is inserted which is comprised of the adenovirus type 2 major late promoter, the adenovirus type 2 tripartite leader cDNA and the human p53 cDNA. It is a typical E1 replacement vector deleted for the Ad5 E1a and E1b genes but containing the Ad5 protein IX gene (for review of Adenovirus vectors see: Graham and Prevec (1992)). Ad2 DNA was obtained from Gibco BRL. Restriction endonucleases and T4 DNA ligase were obtained from New England Biolabs. *E. coli* DH5α competent cells were purchased from Gibco BRL and 293 cells were obtained from the American Type Culture Collection (ATCC). Prep-A-Gene DNA purification resin was obtained from BioRad. LB broth bacterial growth medium was obtained from Difco. Qiagen DNA purification columns were obtained from Qiagen, Inc. Ad5 dl327 was obtained from R.J. Schneider, NYU. The MBS DNA transfection kit was purchased from Stratagene.

One (1) μg pAd/MLP/p53/E1b- was digested with 20 units each of restriction enzymes Ecl 136II and NgoMI according to the manufacturer's recommendations. Five (5) μg Ad2 DNA was digested with 20 units each of restriction endonucleases DraI and NgoMI according to the manufacturer's recommendations. The restriction digestions were loaded into separate lanes of a 0.8% agarose gel and electrophoresed at 100 volts for 2 hours. The 4268 bp restriction fragment from the Pad/MLP/p53/E1b- sample and the 6437 bp fragment from the Ad2 sample were isolated from the gel using Prep-A-Gene DNA extraction resin according to

the manufacturer's specifications. The restriction fragments were mixed and treated with T4 DNA ligase in a total volume of 50 μl at 16°C for 16 hours according to the manufacturer's recommendations. Following ligation 5 μl of the reaction was used to transform *E. coli* DH5α cells to ampicillin resistance following the manufacturer's procedure. Six bacterial colonies resulting from this procedure were used to inoculate separate 2 ml cultures of LB growth medium and incubated overnight at 37°C with shaking. DNA was prepared from each bacterial culture using standard procedures (Sambrook *et al.* (1989)). One fourth of the plasmid DNA from each isolate was digested with 20 units of restriction endonuclease XhoI to screen for the correct recombinant containing XhoI restriction fragments of 3627, 3167, 2466 and 1445 base pairs. Five of six screened isolates contained the correct plasmid. One of these was then used to inoculate a 1 liter culture of LB medium for isolation of large quantities of plasmid DNA. Following overnight incubation plasmid DNA was isolated from the 1 liter culture using Qiagen DNA purification columns according to the manufacturer's recommendations. The resulting plasmid was designated Pad/MLP/p53/PIX-. Samples of this plasmid were deposited with the American Type Culture Collection, 12301 Parklawn Drive, Rockville, Maryland, U.S.A., 12301, on October 22, 1993. The deposit was made under the provisions of the Budapest Treaty on the International Deposit of Microorganisms for the Purpose of Patent Procedure. The deposit was accorded ATCC Accession No. 75576.

To construct a recombinant adenovirus, 10 μg Pad/MLP/p53/PIX- were treated with 40 units of restriction endonuclease EcoRI to linearize the plasmid. Adenovirus type 5 dl327 DNA (Thimmappaya (1982)) was digested with restriction endonuclease ClaI and the large fragment (approximately 33 kilobase pairs) was purified by sucrose gradient centrifugation. Ten (10) μg of EcoRI treated

Pad/MLP/p53/E1b- and 2.5 μg of ClaI treated Ad5 dl327 were mixed and used to transfect approximately 10^6 293 cells using the MBS mammalian transfection kit as recommended by the supplier. Eight (8) days following the transfection the 293 cells were split 1 to 3 into fresh media and two days following this adenovirus induced cytopathic effect became evident on the transfected cells. At 13 days post-transfection DNA was prepared from the infected cells using standard procedures (Graham and Prevec (1991)) and analyzed by restriction digestion with restriction endonuclease XhoI. Virus directed expression of p53 was verified following infection of SaoS2 osteosarcoma cells with viral lysate and immunoblotting with an anti-p53 monoclonal antibody designated 1801 (Novocasta Lab. Ltd., U.K.).

EXPERIMENT NO. II

MATERIALS AND METHODS

Cell Lines

Recombinant adenoviruses were grown and propagated in the human embryonal kidney cell line 293 (ATCC CRL 1573) maintained in DME medium containing 10% defined, supplemented calf serum (Hyclone). Saos-2 cells were maintained in Kaighn's media supplemented with 15% fetal calf serum. HeLa and Hep 3B cells were maintained in DME medium supplemented with 10% fetal calf serum. All other cell lines were grown in Kaighn's media supplemented with 10% fetal calf serum. Saos-2 cells were kindly provided by Dr. Eric Stanbridge. All other cell lines were obtained from ATCC.

Construction of Recombinant Adenoviruses

To construct the Ad5/p53 viruses, a 1.4 kb HindIII-SmaI fragment containing the full length cDNA for

p53 (Table I) was isolated from pGEM1-p53-B-T (kindly supplied by Dr. Wen Hwa Lee) and inserted into the multiple cloning site of the expression vector pSP72 (Promega) using standard cloning procedures (Sambrook *et al.* (1989)). The p53 insert was recovered from this vector following digestion with XhoI-BglII and gel electrophoresis. The p53 coding sequence was then inserted into either pNL3C or pNL3CMV adenovirus gene transfer vectors (kindly provided by Dr. Robert Schneider) which contain the Ad5 5' inverted terminal repeat and viral packaging signals and the E1a enhancer upstream of either the Ad2 major late promoter (MLP) or the human cytomegalovirus immediate early gene promoter (CMV), followed by the tripartite leader CDNA and Ad 5 sequence 3325-5525 bp in a PML2 background. These new constructs replace the E1 region (bp 360-3325) of Ad5 with p53 driven by either the Ad2 MLP (A/M/53) or the human CMV promoter (A/C/53), both followed by the tripartite leader CDNA (see Figure 4). The p53 inserts use the remaining downstream E1b polyadenylation site. Additional MLP and CMV driven p53 recombinants (A/M/N/53, A/C/N/53) were generated which had a further 705 nucleotide deletion of Ad 5 sequence to remove the protein IX (PIX) coding region. As a control, a recombinant adenovirus was generated from the parental PNL3C plasmid without a p53 insert (A/M). A second control consisted of a recombinant adenovirus encoding the beta-galactosidase gene under the control of the CMV promoter (A/C/ß-gal). The plasmids were linearized with either Nru I or Eco RI and co-transfected with the large fragment of a Cla I digested Ad 5 d1309 or d1327 mutants (Jones and Shenk (1979)) using a Ca/PO_4 transfection kit (Stratagene). Viral plaques were isolated and recombinants identified by both restriction digest analysis and PCR using recombinant specific primers against the tripartite leader CDNA sequence with downstream p53 CDNA sequence. Recombinant virus was further purified by limiting dilution, and virus particles were purified and

titered by standard methods (Graham and van der Erb (1973); Graham and Prevec (1991)).

p53 Protein Detection

Saos-2 or Hep 3B cells (5 x 10^5) were infected with the indicated recombinant adenoviruses for a period of 24 hours at increasing multiplicities of infection (MOI) of plaque forming units of virus/cell. Cells were then washed once with PBS and harvested in lysis buffer (50mM Tris-Hcl Ph 7.5, 250 Mm NaCl, 0.1% NP40, 50mM NaF, 5mM EDTA, 10ug/ml aprotinin, 10 ug/ml leupeptin, and 1mM PMSF). Cellular proteins (approximately 30 μg) were separated by 10% SDS-PAGE and transferred to nitrocellulose. Membranes were incubated with α-p53 antibody PAb 1801 (Novocastro) followed by sheep anti-mouse IgG conjugated with horseradish peroxidase. p53 protein was visualized by chemiluminescence (ECL kit, Amersham) on Kodak XAR-5 film.

Measurement of DNA Synthesis Rate

Cells (5 x 10^3/well) were plated in 96-well titer plates (Costar) and allowed to attach overnight (37°C, 7% CO_2). Cells were then infected for 24 hours with purified recombinant virus particles at MOIs ranging from 0.3 to 100 as indicated. Media were changed 24 hours after infection, and incubation was continued for a total of 72 hours. ^{3}H-thymidine (Amersham, 1μCi/well) was added 18 hours prior to harvest. Cells were harvested on glass fiber filters and levels of incorporated radioactivity were measured in a beta scintillation counter. ^{3}H-thymidine incorporation was expressed as the mean % (+/- SD) of media control and plotted versus the MOI.

Tumorigenicity in Nude Mice

Approximately 2.4 x 10^8 Saos-2 cells, plated in T225 flasks, were treated with suspension buffer (1% sucrose in PBS) containing either A/M/N/53 or A/M purified virus at an MOI of 3 or 30. Following an overnight infection, cells were injected subcutaneously into the left and right flanks of BALB/c athymic nude mice (4 mice per group). One flank was injected with the A/M/N/53 treated cells, while the contralateral flank was injected with the control A/M treated cells, each mouse serving as its own control. Animals receiving bilateral injection of buffer treated cells served as additional controls. Tumor dimensions (length, width and height) and body weights were then measured twice per week over an 8 week period. Tumor volumes were estimated for each animal assuming a spherical geometry with radius equal to one-half the average of the measured tumor dimensions.

Intra-tumoral RNA Analysis

BALB/c athymic nude mice (approximately 5 weeks of age) were injected subcutaneously with 1 x 10^7 H69 small cell lung carcinoma (SCLC) cells in their right flanks. Tumors were allowed to progress for 32 days until they were approximately 25-50 mm^3. Mice received peritumoral injections of either A/C/53 or A/C/ß-gal recombinant adenovirus (2 x 10^9 plaque forming units (pfu)) into the subcutaneous space beneath the tumor mass. Tumors were excised from the animals 2 and 7 days post adenovirus treatment and rinsed with PBS. Tumor samples were homogenized, and total RNA was isolated using a TriReagent kit (Molecular Research Center, Inc.). PolyA RNA was isolated using the PolyATract mRNA Isolation System (Promega), and approximately 10 ng of sample was used for RT-PCR determination of recombinant p53 MRNA expression (Wang *et al.* (1989)). Primers were designed to amplify sequence between the adenovirus tripartite leader CDNA and

the downstream p53 CDNA, ensuring that only recombinant, and not endogenous p53 would be amplified.

p53 Gene Therapy of Established Tumors in Nude Mice

Approximately 1 x 10^7 H69 (SCLC) tumor cells in 200μl volumes were injected subcutaneously into female BALB/c athymic nude mice. Tumors were allowed to develop for 2 weeks, at which point animals were randomized by tumor size (N=5/group). Peritumoral injections of either A/M/N/53 or the control A/M adenovirus (2 x 10^9 pfu/injection) or buffer alone (1% sucrose in PBS) were administered twice per week for a total of 8 doses/group. Tumor dimensions and body weights were measured twice per week for 7 weeks, and tumor volume was estimated as described previously. Animals were then followed to observe the effect of treatment on mouse survival.

RESULTS

Construction of Recombinant p53-Adenovirus

p53 adenoviruses were constructed by replacing a portion of the E1a and E1b region of adenovirus Type 5 with p53 CDNA under the control of either the Ad2 MLP (A/M/53) or CMV (A/C/53) promoter (schematized in Figure 4). This E1 substitution severely impairs the ability of the recombinant adenoviruses to replicate, restricting their propagation to 293 cells which supply Ad 5 E1 gene products in *trans* (Graham *et al.* (1977)). After identification of p53 recombinant adenovirus by both restriction digest and PCR analysis, the entire p53 CDNA sequence from one of the recombinant adenoviruses (A/M/53) was sequenced to verify that it was free of mutations. Following this, purified preparations of the p53 recombinants were used to infect HeLa cells to assay for the presence of phenotypically wild type adenovirus. HeLa cells, which are non-permissive for

replication of E1-deleted adenovirus, were infected with 1-4 x 10^9 infectious units of recombinant adenovirus, cultured for 3 weeks, and observed for the appearance of cytopathic effect (CPE). Using this assay, recombinant adenovirus replication or wild type contamination was not detected, readily evident by the CPE observed in control cells infected with wild type adenovirus at a level of sensitivity of approximately 1 in 10^9.

p53 Protein Expression from Recombinant Adenovirus

To determine if p53 recombinant adenoviruses expressed p53 protein, tumor cell lines which do not express endogenous p53 protein were infected. The human tumor cell lines Saos-2 (osteosarcoma) and Hep 3B (hepatocellular carcinoma) were infected for 24 hours with the p53 recombinant adenoviruses A/M/53 or A/C/53 at MOIs ranging 0.1 to 200 pfu/cell. Western analysis of lysates prepared from infected cells demonstrated a dose-dependent p53 protein expression in both cell types (Figure 5). Both cell lines expressed higher levels of p53 protein following infection with A/C/53 than with A/M/53 (Figure 3). No p53 protein was detected in non-infected cells. Levels of endogenous wild-type p53 are normally quite low, and nearly undetectable by Western analysis of cell extracts (Bartek *et al.* (1991)). It is clear however that wild-type p53 protein levels are easily detectable after infection with either A/M/53 or A/C/53 at the lower MOIs (Figure 5), suggesting that even low doses of p53 recombinant adenoviruses can produce potentially efficacious levels of p53.

p53 Dependent Morphology Changes

The reintroduction of wild-type p53 into the p53-negative osteosarcoma cell line, Saos-2, results in a characteristic enlargement and flattening of these normally

spindle-shaped cells (Chen *et al.* (1990)). Subconfluent Saos-2 cells ($1x10^5$ cells/10cm plate) were infected at an MOI of 50 with either the A/C/53 or control A/M virus, and incubated at 37°C for 72 hours until uninfected control plates were confluent. At this point, the expected morphological change was evident in the A/C/53 treated plate (Figure 6, panel C) but not in uninfected (Figure 6, panel A) or control virus-infected plates (Figure 6, panel B). This effect was not a function of cell density because a control plate initially seeded at lower density retained normal morphology at 72 hours when its confluence approximated that of the A/C/53 treated plate. Previous results had demonstrated a high level of p53 protein expression at an MOI of 50 in Saos-2 cells (Figure 5A), and these results provided evidence that the p53 protein expressed by these recombinant adenoviruses was biologically active.

p53 Inhibition of Cellular DNA Synthesis

To further test the activity of the p53 recombinant adenoviruses, their ability to inhibit proliferation of human tumor cells was assayed as measured by the uptake of ^{3}H-thymidine. It has previously been shown that introduction of wild-type p53 into cells which do not express endogenous wild-type p53 can arrest the cells at the G_1/S transition, leading to inhibition of uptake of labeled thymidine into newly synthesized DNA (Baker *et al.* (1990); Mercer *et al.* (1990); Diller *et al.* (1990)). A variety of p53-deficient tumor cell lines were infected with either A/M/N/53, A/C/N/53 or a non-p53 expressing control recombinant adenovirus (A/M). A strong, dose-dependent inhibition of DNA synthesis by both the A/M/N/53 and A/C/N/53 recombinants in 7 out of the 9 different tumor cell lines tested (Figure 7) was observed. Both constructs were able to inhibit DNA synthesis in these human tumor cells, regardless of whether they expressed mutant p53 or

failed to express p53 protein. It also was found that in this assay, the A/C/N/53 construct was consistently more potent than the A/M/N/53. In saos-2 (osteosarcoma) and MDA-MB468 (breast cancer) cells, nearly 100% inhibition of DNA synthesis was achieved with the A/C/N/53 construct at an MOI as low as 10. At doses where inhibition by the control adenovirus in only 10-30%, a 50-100% reduction in DNA synthesis using either p53 recombinant adenovirus was observed. In contrast, no significant p53-specific effect was observed with either construct as compared to control virus in HEP G2 cells (hepatocarcinoma cell line expressing endogenous wild-type p53, Bressac *et al.* (1990)), nor in the K562 (p53 null) leukemic cell line.

Tumorigenicity in Nude Mice

In a more stringent test of function for the p53 recombinant adenoviruses, tumor cells were infected *ex vivo* and then injected the cells into nude mice to assess the ability of the recombinants to suppress tumor growth *in vivo*. Saos-2 cells infected with A/M/N/53 or control A/M virus at a MOI of 3 or 30, were injected into opposite flanks of nude mice. Tumor sizes were then measured twice a week over an 8 week period. At the MOI of 30, no tumor growth was observed in the p53-treated flanks in any of the animals, while the control treated tumors continued to grow (Figure 8). The progressive enlargement of the control virus treated tumors were similar to that observed in the buffer treated control animals. A clear difference in tumor growth between the control adenovirus and the p53 recombinant at the MOI of 3, although tumors from 2 out of the 4 p53-treated mice did start to show some growth after approximately 6 weeks. Thus, the A/M/N/53 recombinant adenovirus is able to mediate p53-specific tumor suppression in an *in vivo* environment.

In Vivo Expression of Ad/p53

Although *ex vivo* treatment of cancer cells and subsequent injection into animals provided a critical test of tumor suppression, a more clinically relevant experiment is to determine if injected p53 recombinant adenovirus could infect and express p53 in established tumors *in vivo*. To address this, H69 (SCLC, $p53^{null}$) cells were injected subcutaneously into nude mice, and tumors were allowed to develop for 32 days. At this time, a single injection of 2×10^9 pfu of either A/C/53 or A/C/ß-gal adenovirus was injected into the peritumoral space surrounding the tumor. Tumors were then excised at either Day 2 or Day 7 following the adenovirus injection, and polyA RNA was isolated from each tumor. RT-PCR, using recombinant-p53 specific

primers, was then used to detect p53 MRNA in the p53 treated tumors (Figure 9, lanes 1,2,4,5). No p53 signal was evident from the tumors excised from the ß-gal treated animals (Figure 9, lanes 3 and 6). Amplification with actin primers served as a control for the RT-PCR reaction (Figure 9, lanes 7-9), while a plasmid containing the recombinant-p53 sequence served as a positive control for the recombinant-p53 specific band (Figure 9, lane 10). This experiment demonstrates that a p53 recombinant adenovirus can specifically direct expression of p53 mRNA within established tumors following a single injection into the peritumoral space. It also shows *in vivo* viral persistence for at least one week following infection with a p53 recombinant adenovirus.

In Vivo Efficacy

To address the feasibility of gene therapy of established tumors, a tumor-bearing nude mouse model was used. H69 cells were injected into the subcutaneous space on the right flank of mice, and tumors were allowed to grow for 2 weeks. Mice then received peritumoral injections of buffer or recombinant virus twice weekly for a total of 8 doses. In the mice treated with buffer or control A/M virus, tumors continued to grow rapidly throughout the treatment, whereas those treated with the A/M/N/53 virus grew at a greatly reduced rate (Figure 10A). After cessation of injections, the control treated tumors continued to grow while the p53 treated tumors showed little or no growth for at least one week in the absence of any additional supply of exogenous p53 (Figure 10A). Although control animals treated with buffer alone had accelerated tumor growth as compared to either virus treated group, no significant difference in body weight was found between the three groups during the treatment period. Tumor ulceration in some animals limited the relevance of tumor size measurements after day 42. However, continued

monitoring of the animals to determine survival time demonstrated a survival advantage for the p53-treated animals (Figure 10B). The last of the control adenovirus treated animals died on day 83, while buffer alone treated controls had all expired by day 56. In contrast, all 5 animals treated with the A/M/N/53 continue to survive (day 130 after cell inoculation) (Figure 10B). Together, this data establish a p53-specific effect on both tumor growth and survival time in animals with established p53-deficient tumors.

Adenovirus Vectors Expressing p53

Recombinant human adenovirus vectors which are capable of expressing high levels of wild-type p53 protein in a dose dependent manner were constructed. Each vector contains deletions in the E1a and E1b regions which render the virus replication deficient (Challberg and Kelly (1979); Horowitz, (1991)). Of further significance is that these deletions include those sequences encoding the E1b 19 and 55 kd protein. The 19 kd protein is reported to be involved in inhibiting apoptosis (White *et al.* (1992); Rao *et al.* (1992)), whereas the 55 kd protein is able to bind wild-type p53 protein (Sarnow *et al.* (1982); Heuvel *et al.* (1990)). By deleting these adenoviral sequences, potential inhibitors of p53 function were removed through direct binding to p53 or potential inhibition of p53 mediated apoptosis. Additional constructs were made which have had the remaining 3' E1b sequence, including all protein IX coding sequence, deleted as well. Although this has been reported to reduce the packaging size capacity of adenovirus to approximately 3 kb less than wild-type virus (Ghosh-Choudhury *et al.* (1987)), these constructs are also deleted in the E3 region so that the A/M/N/53 and A/C/N/53 constructs are well within this size range. By deleting the pIX region, adenoviral sequences homologous to those contained in 293 cells are reduced to approximately 300

base pairs, decreasing the chances of regenerating replication-competent, wild-type adenovirus through recombination. Constructs lacking pIX coding sequence appear to have equal efficacy to those with pIX.

p53/Adenovirus Efficacy *In Vitro*

In concordance with a strong dose dependency for expression of p53 protein in infected cells, a dose-dependent, p53-specific inhibition of tumor cell growth was demonstrated. Cell division, was inhibited and demonstrated by the inhibition of DNA synthesis, in a wide variety of tumor cell types known to lack wild-type p53 protein expression. Bacchetti and Graham (1993) recently reported p53 specific inhibition of DNA synthesis in the ovarian carcinoma cell line SKOV-3 by a p53 recombinant adenovirus in similar experiments. In addition to ovarian carcinoma, additional human tumor cell lines were demonstrated, representative of clinically important human cancers and including lines over-expressing mutant p53 protein, can also be growth inhibited by the p53 recombinants of this invention. At MOIs where the A/C/N/53 recombinant is 90-100% effective in inhibiting DNA synthesis in these tumor types, control adenovirus mediated suppression is less than 20%.

Although Feinstein *et al.* (1992) reported that re-introduction of wild-type p53 could induce differentiation and increase the proportion of cells in G_1 versus $S+G_2$ for leukemic K562 cells, no p53 specific effect was found in this line. Horvath and Weber (1988) have reported that human peripheral blood lymphocytes are highly nonpermissive to adenovirus infection. In separate experiments, the recombinant significantly infected the non-responding K562 cells with recombinant A/C/ß-gal adenovirus, while other cell lines, including the control Hep G2 line and those showing a strong p53 effect, were

readily infectable. Thus, at least part of the variability of efficacy would appear to be due to variability of infection, although other factors may be involved as well.

The results observed with the A/M/N/53 virus in Figure 8 demonstrates that complete suppression is possible in an *in vivo* environment. The resumption of tumor growth in 2 out of 4, p53 treated animals at the lower MOI most likely resulted from a small percentage of cells not initially infected with the p53 recombinant at this dose. The complete suppression seen with A/M/N/53 at the higher dose, however, shows that the ability of tumor growth to recover can be overcome.

p53/Adenovirus *In Vivo* Efficacy

Work presented here and by other groups (Chen *et al.* (1990); Takahashi *et al.* (1992)) have shown that human tumor cells lacking expression of wild-type p53 can be treated *ex vivo* with p53 and result in suppression of tumor growth when the treated cells are transferred into an animal model. Applicants present the first evidence of tumor suppressor gene therapy of an *in vivo* established tumor, resulting in both suppression of tumor growth and increased survival time. In Applicants' system, delivery to tumor cells did not rely on direct injection into the tumor mass. Rather, p53 recombinant adenovirus was injected into the peritumoral space, and p53 mRNA expression was detected within the tumor. p53 expressed by the recombinants was functional and strongly suppressed tumor growth as compared to that of control, non-p53 expressing adenovirus treated tumors. However, both p53 and control virus treated tumor groups showed tumor suppression as compared to buffer treated controls. It has been demonstrated that local expression of tumor necrosis factor (TNF), interferon-γ), interleukin (IL)-2, IL-4 or IL-7 can lead to T-cell independent transient tumor

suppression in nude mice (Hoch *et al.* (1992)). Exposure of monocytes to adenovirus virions are also weak inducers of IFN-α/ß (reviewed in Gooding and Wold (1990)). Therefore, it is not surprising that some tumor suppression in nude mice was observed even with the control adenovirus. This virus mediated tumor suppression was not observed in the *ex vivo* control virus treated Saos-2 tumor cells described earlier. The p53-specific *in vivo* tumor suppression was dramatically demonstrated by continued monitoring of the animals in Figure 10. The survival time of the p53-treated mice was significantly increased, with 5 out of 5 animals still alive more than 130 days after cell inoculation compared to 0 out of 5 adenovirus control treated animals. The surviving animals still exhibit growing tumors which may reflect cells not initially infected with the p53 recombinant adenovirus. Higher or more frequent dosing schedules may address this. In addition, promoter shutoff (Palmer *et al.* (1991)) or additional mutations may have rendered these cells resistant to the p53 recombinant adenovirus treatment. For example, mutations in the recently described WAF1 gene, a gene induced by wild-type p53 which subsequently inhibits progression of the cell cycle into S phase, (El-Deiry *et al.* (1993); Hunter (1993)) could result in a p53-resistant tumor.

EXPERIMENT NO. III

This Example shows the use of suicide genes and tissue specific expression of such genes in the gene therapy methods described herein. Hepatocellular carcinoma was chosen as the target because it is one of the most common human malignancies affecting man, causing an estimated 1,250,000 deaths per year world-wide. The incidence of this cancer is very high in Southeast Asia and Africa where it is associated with Hepatitis B and C infection and exposure to aflatoxin. Surgery is currently the only treatment which offers the potential for curing

HCC, although less than 20% of patients are considered candidates for resection (Ravoet C. et al., 1993). However, tumors other than hepatocellular carcinoma are equally applicable to the methods of reducing their proliferation described herein.

CELL LINES

All cell lines but for the HLF cell line were obtained from the American Type Tissue Culture Collection (ATCC) 12301 Parklawn Drive, Rockville Maryland. ATCC accession numbers are noted in parenthesis. The human embryonal kidney cell line 293 (CRL 1573) was used to generate and propagate the recombinant adenoviruses described herein. They were maintained in DME medium containing 10% defined, supplemented calf serum (Hyclone). The hepatocellular carcinoma cell lines Hep 3B (HB 8064), Hep G2 (HB 8065), and HLF were maintained in DME/F12 medium supplemented with 10% fetal bovine serum, as were the breast carcinoma cell lines MDA-MB468 (HTB 132) and BT-549 (HTB 122). Chang liver cells (CCL 13) were grown in MEM medium supplemented with 10% fetal bovine serum. The HLF cell line was obtained from Drs. T. Morsaki and H. Kitsuki at the Kyushu University School of Medicine in Japan.

RECOMBINANT VIRUS CONSTRUCTION

Two adenoviral expression vectors designated herein as ACNTK and AANTK and devoid of protein IX function (depicted in Figure 11) are capable of directing expression of the TK suicide gene within tumor cells. A third adenovirus expression vector designated AANCAT was constructed to further demonstrate the feasibility of specifically targeting gene expression to specific cell types using adenoviral vectors. These adenoviral constructs were assembled as depicted in Figures 11 and 12 and are derivatives of those previously described for the expression of tumor suppresor genes.

For expression of the foreign gene, expression cassettes have been inserted that utilize either the human cytomegalovirus immediate early promoter/enhancer (CMV) (Boshart, M. et al., 1985) or the human alpha-fetoprotein (AFP) enhancer/promoter (Watanable, K. et al., 1987; Nakabayashi, H. et al., 1989) to direct transcription of the TK gene or the chloramphenicol acetyltransferase gene (CAT). The CMV enhancer promoter is capable of directing robust gene expression in a wide variety of cell types while the AFP enhancer/promoter construct restricts expression to hepatocellular carcinoma cells (HCC) which express AFP in about 70-80% of the HCC pateint population. In the construct utilizing the CMV promoter/enhancer, the adenovirus type 2 tripartite leader sequence also was inserted to enhance translation of the TK transcript (Berkner, K.L. and Sharp, 1985). In addition to the E1 deletion, both adenovirus vectors are additionally deleted for 1.9 kilobases (kb) of DNA in the viral E3 region. The DNA deleted in the E3 region is non-essential for virus propagation and its deletion increases the insert capacity of the recombinant virus for foreign DNA by an equivalent amount (1.9kb) (Graham and Prevec, 1991).

To demonstrate the specificity of the AFP promoter/enhancer, the virus AANCAT also was constructed where the marker gene chloramphenicol aceytitransferase (CAT) is under the control of the AFP enhancer/promoter. In the ACNTK viral construct, the Ad2 tripartite leader sequence was placed between the CMV promoter/enhancer and the TK gene. The tripartite leader has been reported to enhance translation of linked genes. The E1 substitution impairs the ability of the recombinant viruses to replicate, restricting their propagation to 293 cells which supply the Ad5 E1 gene products in trans (Graham et al., 1977).

Adenoviral Vector ACNTK: The plasmid pMLBKTK in E. coli HB101 (from ATCC #39369) was used as the source of the herpes simplex virus (HSV-1) thymidine kinase (TK) gene. TK was excised from this plasmid as a 1.7 kb gene fragment by digestion with the restriction enzymes Bgl II and Pvu II and subcloned into the compatible Bam HI, EcoR V restriction sites of plasmid pSP72 (Promega) using standard cloning techniques (Sambrook et al., 1989). The TK insert was then isolated as a 1.7 kb fragment from this vector by digestion with Xba I and Bgl II and cloned into Xba I, BamHI digested plasmid pACN (Wills et al. 1994). Twenty (20) μg of this plasmid designated pACNTK were linearized with Eco RI and cotransfected into 293 cells (ATCC CRL 1573) with 5 μg of Cla I digested ACBGL (Wills et al., 1994 supra) using a $CaPO_4$ transfection kit (Stratagene, San Diego, California). Viral plaques were isolated and recombinants, designated ACNTK, were identified by restriction digest analysis of isolated DNA with Xho I and BsiWI. Positive recombinants were further purified by limiting dilution and expanded and titered by standard methods (Graham and Prevec, 1991).

Adenoviral Vector AANTK: The α-fetoprotein promoter (AFP-P) and enhancer (AFP-E) were cloned from a human genomic DNA (Clontech) using PCR amplification with primers containing restriction sites at their ends. The primers used to isolate the 210 bp AFP-E contained a Nhe I restriction site on the 5′ primer and an Xba I, Xho I, Kpn I linker on the 3′ primer. The 5′ primer sequence was 5′-CGC GCT AGC TCT GCC CCA AAG AGC T-3. The 5′ primer sequence was 5′-CGC GGT ACC CTC GAG TCT AGA TAT TGC CAG TGG TGG AAG-3′. The primers used to isolate the 1763 bp AFE fragment contained a Not I restriction site on the 5′ primer and a Xba I site on the 3′ primer. The 5′ primer sequence was 5′-CGT GCG GCC GCT GGA GGA CTT TGA GGA TGT CTG TC-3′. The 3′ primer sequence was 5′-CGC TCT AGA GAG ACC AGT TAG GAA GTT TTC GCA-3′. For PCR amplification, the DNA

was denatured at 97° for 7 minutes, followed by 5 cycles of amplification at 97°, 1 minute, 53°, 1 minute, 72°, 2 minutes, and a final 72°, 10 minute extension. The amplified AFE was digested with Not I and Xba I and inserted into the Not I, Xba I sites of a plasmid vector (pA/ITR/B) containing adenovirus type 5 sequences 1-350 and 3330 - 5790 separated by a polylinker containing Not I, Xho I, Xba I, Hind III, Kpn I, Bam HI, Nco I, Sma I, and Bgl II sites. The amplified AFP-E was digested with Nhe I and Kpn I and inserted into the AFP-E containing construct described above which had been digested with Xba I and Kpn I. This new construct was then further digested with Xba I and NgoMI to remove adenoviral sequences 3330 - 5780, which were subsequently replaced with an Xba I, NgoMI restriction fragment of plasmid pACN containing nucleotides 4021 - 10457 of adenovirus type 2 to construct the plasmid pAAN containing both the α-fetoprotein enhancer and promoter. This construct was then digested with Eco RI and Xba I to isolate a 2.3 kb fragment containing the Ad5 inverted terminal repeat, the AFP-E and the AFP-P which was subsequently ligated with the 8.55 kb fragment of Eco RI, Xba I digested pACNTK described above to generate pAANTK where the TK gene is driven by the α-fetoprotein enhancer and promoter in an adenovirus background. This plasmid was then linearized with Eco RI and cotransfected with the large fragment of Cla I digested ALBGL as above and recombinants, designated AANTK, were isolated and purified as described above.

Adenoviral Vector AANCAT: The chloramphenicol acetyltransferase (CAT) gene was isolated from the pCAT-Basic Vector (Promega Corporation) by an Xba I, Bam HI digest. This 1.64 kb fragment was ligated into Xba I, Bam HI digested pAAN (described above) to create pAANCAT. This plasmid was then linearized with Eco RI and cotransfected with the large fragment of Cla I digested rA/C/ß-gal to create AANCAT.

REPORTER GENE EXPRESSION: ß-GALACTOSIDASE EXPRESSION:

Cells were plated at 1 x 10^5 cells/well in a 24-well tissue culture plate (Costar) and allowed to adhere overnight (37C, 7% CO_2). Overnight infections of ACBGL were performed at a multiplicity of infection (MOI) of 30. After 24 hours, cells were fixed with 3.7% Formaldehyde; PBS, and stained with 1mg/ml Xgal reagent (USB). The data was scored (+,++,+++) by estimating the percentage of positively stained cells at each MOI. [+=1-33%, ++=33-67% and +++=>67%]

REPORTER GENE EXPRESSION: CAT EXPRESSION:

Two (2) x 10^6 cells (Hep G2, Hep 3B, HLF, Chang, and MDA-MB468) were seeded onto 10 cm plates in triplicate and incubated overnight (37C, 7% CO_2). Each plate was then infected with either AANCAT at an MOI = 30 or 100 or uninfected and allowed to incubate for 3 days. The cells were then trypsinized and washed with PBS and resuspended in 100 µl of 0.25 M Tris pH 7.8. The samples were frozen and thawed 3 times, and the supernatant was transferred to new tubes and incubated at 60°C for 10 minutes. The samples were then spun at 4°C for 5 minutes, and the supernatants assayed for protein concentration using a Bradford assay (Bio-Rad Protein Assay Kit). Samples were adjusted to equal protein concentrations to a final volume of 75 µl using 0.25 M Tris, 25 µl of 4mM acetyl CoA and 1 µl of ^{14}C-Chloramphenicol and incubated overnight at 37°C. 500 µl of ethyl acetate is added to each sample and mixed by vortexing, followed by centrifiguration for 5 minutes at room temperature. The upper phase is then transferred to a new tube and the ethyl acetate is evaporated by centrifugation under vacuum. The reaction products are then redissolved in 25 µl of ethyl acetate and spotted onto a thin layer chromatography (TLC) plate and the plate is then placed in a pre-equilibrated TLC chamber (95%

chloroform, 5% methanol). The solvent is then allowed to migrate to the top of the plate, the plate is then dried and exposed to X-ray film.

CELLULAR PROLIFERATION: ^{3}H-THYMIDINE INCORPORATION

Cells were plated at 5 x 10^3 cells/well in a 96-well micro-titer plate (Costar) and allowed to incubate overnight (37C, 7% CO_2). Serially diluted ACN, ACNTK or AATK virus in DMEM; 15% FBS; 1% glutamine was used to transfect cells at an infection multiplicity of 30 for an overnight duration at which point cells were dosed in triplicate with ganciclovir (Cytovene) at log intervals betweem 0.001 and 100 mM (micro molar). 1 μCi ^{3}H-thymidine (Amersham) was added to each well 12-18 hours before harvesting. At 72 hours-post infection cells were harvested onto glass-fiber filters and incorporated ^{3}H-thymidine was counted using liquid scintillation (TopCount, Packard). Results are plotted as percent of untreated control proliferation and tabulated as the effective dose (ED_{50}±SD) for a 50 percent reduction in proliferation over media controls. ED_{50} values were estimated by fitting a logistic equation to the dose response data.

CYTOTOXICITY: LDH RELEASE

Cells (HLF, human HCC) were plated, infected with ACN or ACNTK and treated with ganciclovir as described for the proliferation assay. At 72 hours post-ganciclovir administration, cells were spun, the supernatant was removed. The levels of lactate dehydrogenase measured colometrically (Promega, Cytotox 96™). Mean (+/- S.D.) LDH release is plotted versus M.O.I.

IN VIVO THERAPY

Human hepatocellular carcinoma cells (Hep 3B) were injected subcutaneously into ten female (10) athymic nu/nu mice (Simonsen Laboratories, Gilroy, CA). Each animal received approximately 1 x 10^7 cells in the left flank. Tumors were allowed to grow for 27 days before randomizing mice by tumor size. Mice were treated with intratumoral and peritumoral injections of ACNTK or the control virus ACN (1 x 10^9 iu in 100 μl) every other day for a total of three doses. Starting 24 hours after the initial dose of adenovirus, the mice were dosed intraperitoneally with ganciclovir (Cytovene 100 mg/kg) daily for a total of 10 days. Mice were monitored for tumor size and body weight twice weekly. Measurements on tumors were made in three dimensions using vernier calipers and volumes were calculated using the formula 4/3 π r^3, where r is one-half the average tumor dimension.

RESULTS

The recombinant adenoviruses were used to infect three HCC cell lines (HLF, Hep3B and Hep-G2). One human liver cell line (Chang) and two breast cancer cell lines were used as controls (MDAMB468 and BT549). To demonstrate the specificity of the AFP promoter/enhancer, the virus AANCAT was constructed. This virus was used to infect cells that either do (Hep 3B, HepG2) or do not (HLE, Chang, MDAMB468) express the HCC tumor marker alpha-fetoprotein (AFP). As shown in Figure 13, AANCAT directs expression of the CAT marker gene only in those HCC cells which are capable of expressing AFP (Figure 13).

The efficacy of ACNTK and AANTK for the treatment of HCC was assessed using a ^{3}H-thymidine incorporation assay to measure the effect of the combination of HSV-TK expression and ganciclovir treatment upon cellular proliferation. The cell lines were infected with either ACNTK or AANTK or the control virus ACN (Wills et al., 1994

supra), which does not direct expression of HSV-TK, and then treated with increasing concentrations of ganciclovir. The effect of this treatment was assessed as a function of increasing concentrations of ganciclovir, and the concentration of ganciclovir required to inhibit ^{3}H-thymidine incorporated by 50% was determined (ED_{50}). Additionally, a relative measure of adenovirus - mediated gene transfer and expression of each cell line was determined using a control virus which directs expression of the marker gene beta-galactosidase. The data presented in Figure 14 and Table 1 below show that the ACNTK virus/ganciclovir combination treatment was capable of inhibiting cellular proliferation in all cell lines examined as compared with the control adenovirus ACN in combination with ganciclovir. In contrast, the AANTK viral vector was only effective in those HCC cell lines which have been demonstrated to express α-fetoprotein. In addition, the AANTK/GCV combination was more effective when the cells were plated at high densities.

TABLE 1

Cell Line	aFP	ß-gal Expression	ACN	ED50 ACNTK	AANTK
MDAMB468	-	+++	>100	2	>100
BT549	-	+++	>100	<0.3	>100
HLF	-	+++	>100	0.8	>100
CHANG	-	+++	>100	22	>100
HEP-3B	-	+	80	8	8
HEP-G2 LOW	+	++	90	2	35
HEP-G2 HIGH	+	++	89	0.5	4

Nude mice bearing Hep3B tumors (N=5/group) were treated intratumorally and peritumorally with equivalent

doses of ACNTK or ACN control. Twenty-four hours after the first administration of recombinant adenovirus, daily treatment of ganciclovir was initiated in all mice. Tumor dimensions from each animal were measured twice weekly via calipers, and average tumor sizes are plotted in Figure 16. Average tumor size at day 58 was smaller in the ACNTK-treated animals but the difference did not reach statistical significance ($p<0.09$, unpaired t-test). These data support a specific effect of ACNTK on tumor growth in vivo. No significant differences in average body weight were detected between the groups.

Although the invention has been described with reference to the above embodiments, it should be understood that various modifications can be made without departing from the spirit of the invention. Accordingly, the invention is limited only by the claims that follow.

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What is claimed is:

1. A recombinant adenovirus expression vector comprising a partial or total deletion of a protein IX DNA and a gene encoding a foreign protein.

2. The recombinant adenovirus expression vector of claim 1, wherein the deletion of the protein IX gene sequence extends from about 3500 bp from the 5′ viral termini to about 4000 bp from the 5′ viral termini.

3. The recombinant adenovirus expression vector of claim 2 further comprising deletion of a non-essential DNA sequence in adenovirus early region 3 and/or early region 4.

4. The recombinant adenovirus expression vector of claim 2 further comprising deletion of a DNA sequences designated adenovirus E1a and E1b.

5. The recombinant adenovirus expression vector of claim 2 further comprising deletion of early region 3 and/or 4 and DNA sequences designated adenovirus E1a and E1b.

6. The recombinant adenovirus expression vector of claim 4 or 5 further comprising a deletion of up to forty nucleotides positioned 3′ to the E1a and E1b and protein IX deletion and a foreign DNA molecule encoding a polyadenylation signal.

7. The recombinant adenovirus expression vector of claims 1 to 6, wherein the adenovirus is a Group C adenovirus selected from a serotype 1, 2, 5 or 6.

8. The recombinant adenovirus expression vector of claim 1, wherein the gene is a DNA molecule up to 2.6 kilobases.

9. The recombinant adenovirus expression vector of claim 6, wherein the gene is a DNA molecule up to 4.5 kilobases.

10. The recombinant adenovirus expression vector of claim 1, wherein the gene encodes a foreign functional protein or a biologically active fragment thereof.

11. The recombinant adenovirus expression vector of claim 10, wherein the gene encodes a foreign functional tumor suppressor protein or a biologically active fragment thereof.

12. The recombinant adenovirus expression vector of claim 1, wherein the gene encodes a suicide protein or functional equivalent thereof.

13. A transformed host cell comprising the recombinant adenovirus expression vector of claim 1 or 10.

14. The transformed host cell of claim 13, wherein the host cell is a procaryotic or eucaryotic cell.

15. A method for transforming a pathologic hyperproliferative mammalian cell comprising contacting the cell with the expression vector of claim 1.

16. A method of treating a pathology in an animal or mammal caused by the absence of a tumor suppressor gene or the presence of a pathologically mutated tumor suppressor gene comprising administering to the animal or mammal an effective amount of the vector of claim 1 containing a gene encoding a foreign functional protein

having a tumor suppressive function, under suitable conditions.

17. The method of claim 16, wherein the foreign protein is a functional tumor suppressor protein.

18. A method of gene therapy comprising administering to a subject an effective amount of the vector of claim 1.

19. A method of inhibiting the proliferation of a tumor in an animal comprising administering an effective amount of the adenoviral expression vector of claim 1 under suitable conditions to the animal.

20. The method of claim 19, wherein the gene encodes an anti-tumor agent.

21. The method of claim 20, wherein the anti-tumor agent is a tumor suppressor gene.

22. The method of claim 20, wherein the anti-tumor agent is a suicide gene or functional equivalent thereof.

23. The method of claim 21, wherein the tumor is non-small cell lung cancer, small cell lung cancer, hepatocarcinoma, melanoma, retinoblastoma, breast tumor, colorectal carcinoma, leukemia, lymphoma, brain tumor, cervical carcinoma, sarcoma, prostate tumor, bladder tumor, tumor of the reticuloendothelial tissues, Wilm's tumor, astrocytoma, glioblastoma, neuroblastoma, ovarian carcinoma, osteosarcoma, and renal cancer.

24. The method of claim 19, wherein the vector is administered by intra-tumoral injection.

25. A pharmaceutical composition comprising the recombinant adenoviral expression vector of claim 1, 10 or 12.

26. A method for reducing the proliferation of tumor cells in a subject comprising administering under suitable conditions an effective amount of an adenoviral expression vector of claim 12 and an effective amount of a thymidine kinase metabolite or a functional equivalent thereof.

27. The method of claim 26, wherein the thymidine kinase metabolite is ganciclovir or 6-methoxypurine arabinonucleoside or a functional equivalent thereof.

28. The method of claim 26, wherein the adenoviral expression vector is administered by injection into the tumor mass.

29. The method of claim 26, wherein the tumor cells are hepatocellular carcinoma.

30. The method of claim 29, wherein the adenoviral expression vector is administered directly into the hepatic artery of the subject.

31. A kit for reducing the proliferation of tumor cells comprising the components of the adenoviral expression vector of claim 12, a thymidine kinase metabolite or functional equivalent thereof, pharmaceutical carriers and instructions for the treatment of hepatocellular carcinoma using the kit components.

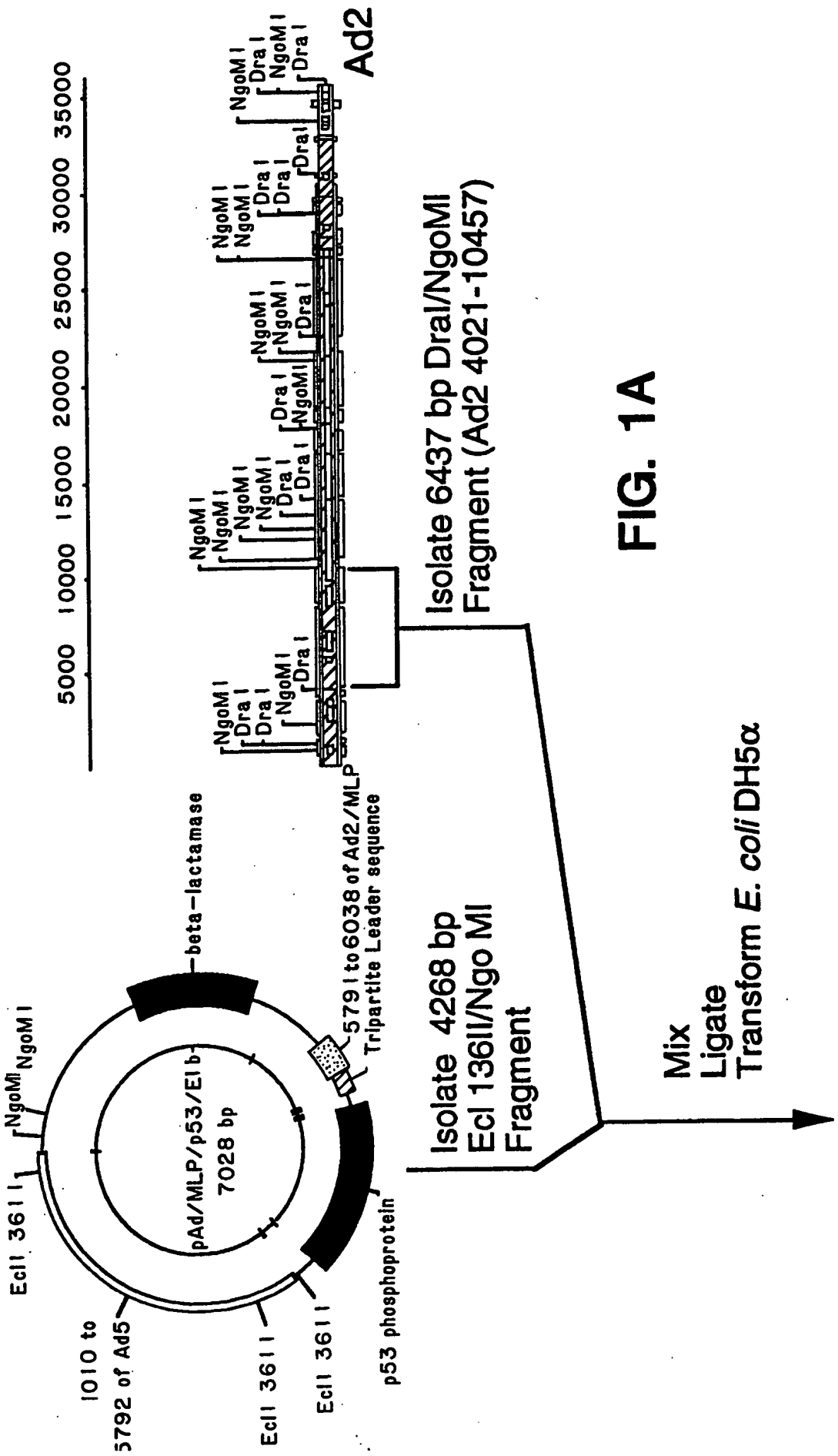

5000 10000 15000 20000 25000 30000 35000
Ad2
NgoM I
Dra I
Isolate 6437 bp DraI/NgoMI
Fragment (Ad2 4021-10457)
Isolate 4268 bp
EcI 136II/Ngo MI
Fragment
Mix
Ligate
Transform E. coli DH5α
beta-lactamase
pAd/MLP/p53/Elb
7028 bp
5791 to 6038 of Ad2/MLP
Tripartite Leader sequence
p53 phosphoprotein
EcII 3611
1010 to
5792 of Ad5

FIG. 1A

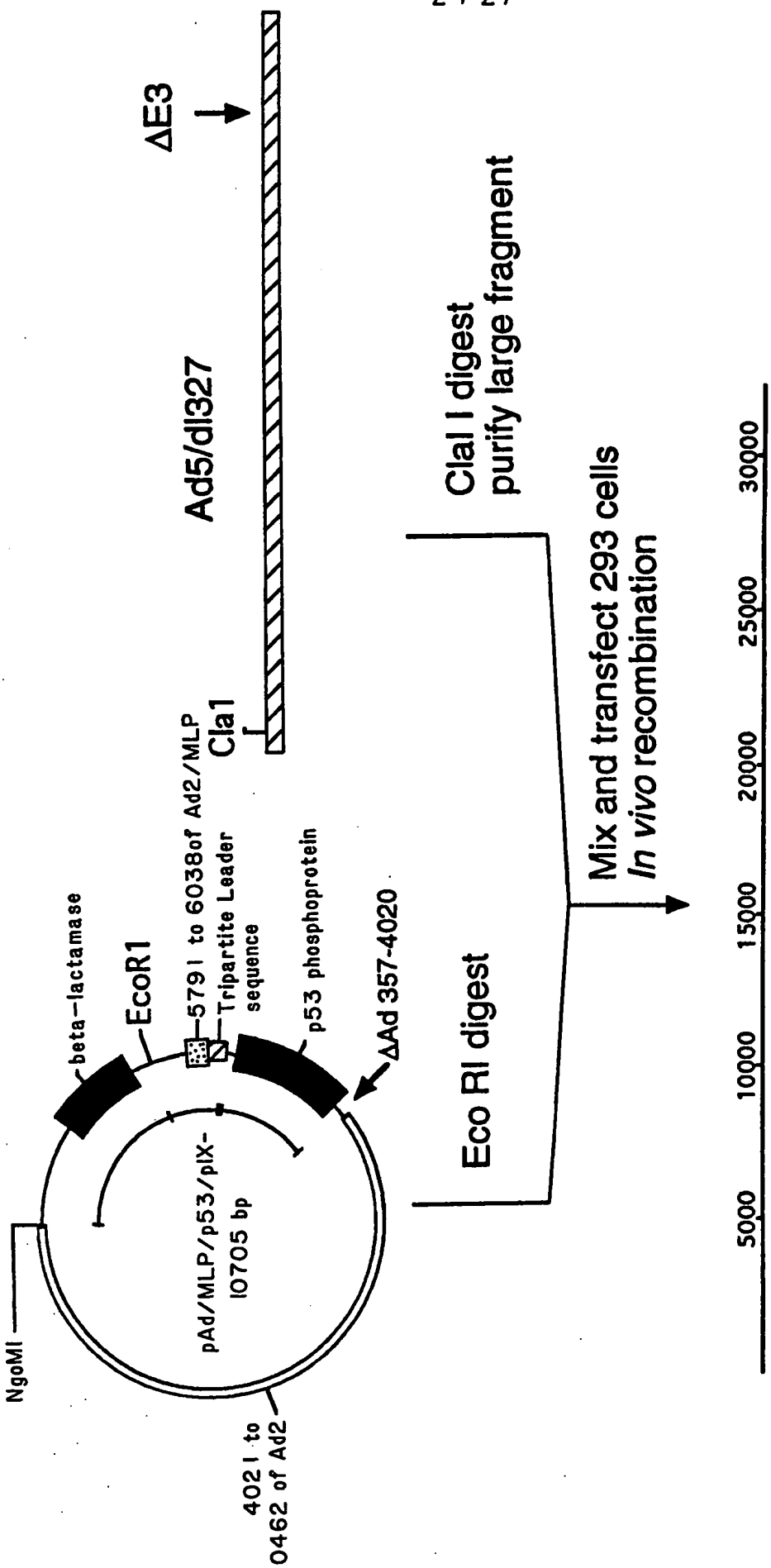

ΔE3
Ad5/dl327
Cla1
5791 to 6038of Ad2/MLP
Tripartite Leader sequence
p53 phosphoprotein
ΔAd 357-4020
beta-lactamase
EcoR1
NgoMI
pAd/MLP/p53/plX-
10705 bp
4021 to
0462 of Ad2
Eco RI digest
ClaI I digest
purify large fragment
Mix and transfect 293 cells
In vivo recombination
5000
10000
15000
20000
25000
30000
rA/M/N/53
ΔE3
Delete Ad5 base pairs 357 to 4020
Insert MLP/p53 cDNA

FIG. 1B

```
Met Pro Pro Lys Thr Pro Arg Lys Thr Ala Ala Thr Ala Ala Ala Ala
 1               5                  10                  15

Ala Ala Glu Pro Pro Ala Pro Pro Pro Pro Pro Pro Glu Glu Asp
            20                  25                  30

Pro Glu Gln Asp Ser Gly Pro Glu Asp Leu Pro Leu Val Arg Leu Glu
        35                  40                  45

Phe Glu Glu Thr Glu Glu Pro Asp Phe Thr Ala Leu Cys Gln Lys Leu
    50                  55                  60

Lys Ile Pro Asp His Val Arg Glu Arg Ala Trp Leu Thr Trp Glu Lys
65                  70                  75                  80

Val Ser Ser Val Asp Gly Val Leu Gly Gly Tyr Ile Gln Lys Lys Lys
                85                  90                  95

Glu Leu Trp Gly Ile Cys Ile Phe Ile Ala Ala Val Asp Leu Asp Glu
            100                 105                 110

Met Ser Phe Thr Phe Thr Glu Leu Gln Lys Asn Ile Glu Ile Ser Val
        115                 120                 125

His Lys Phe Phe Asn Leu Leu Lys Glu Ile Asp Thr Ser Thr Lys Val
    130                 135                 140

Asp Asn Ala Met Ser Arg Leu Leu Lys Lys Tyr Asp Val Leu Phe Ala
145                 150                 155                 160

Leu Phe Ser Lys Leu Glu Arg Thr Cys Glu Leu Ile Tyr Leu Thr Gln
                165                 170                 175

Pro Ser Ser Ser Ile Ser Thr Glu Ile Asn Ser Ala Leu Val Leu Lys
            180                 185                 190

Val Ser Trp Ile Thr Phe Leu Leu Ala Lys Gly Glu Val Leu Gln Met
        195                 200                 205

Glu Asp Asp Leu Val Ile Ser Phe Gln Leu Met Leu Cys Val Leu Asp
    210                 215                 220

Tyr Phe Ile Lys Leu Ser Pro Pro Met Leu Leu Lys Glu Pro Tyr Lys
225                 230                 235                 240

Thr Ala Val Ile Pro Ile Asn Gly Ser Pro Arg Thr Pro Arg Arg Gly
                245                 250                 255
```

FIG. 2A

```
Gln Asn Arg Ser Ala Arg Ile Ala Lys Gln Leu Glu Asn Asp Thr Arg
            260                 265                 270

Ile Ile Glu Val Leu Cys Lys Glu His Glu Cys Asn Ile Asp Glu Val
        275                 280                 285

Lys Asn Val Tyr Phe Lys Asn Phe Ile Pro Phe Met Asn Ser Leu Gly
    290                 295                 300

Leu Val Thr Ser Asn Gly Leu Pro Glu Val Glu Asn Leu Ser Lys Arg
305                 310                 315                 320

Tyr Glu Glu Ile Tyr Leu Lys Asn Lys Asp Leu Asp Ala Arg Leu Phe
                325                 330                 335

Leu Asp His Asp Lys Thr Leu Gln Thr Asp Ser Ile Asp Ser Phe Glu
            340                 345                 350

Thr Gln Arg Thr Pro Arg Lys Ser Asn Leu Asp Glu Glu Val Asn Val
        355                 360                 365

Ile Pro Pro His Thr Pro Val Arg Thr Val Met Asn Thr Ile Gln Gln
    370                 375                 380

Leu Met Met Ile Leu Asn Ser Ala Ser Asp Gln Pro Ser Glu Asn Leu
385                 390                 395                 400

Ile Ser Tyr Phe Asn Asn Cys Thr Val Asn Pro Lys Glu Ser Ile Leu
                405                 410                 415

Lys Arg Val Lys Asp Ile Gly Tyr Ile Phe Lys Glu Lys Phe Ala Lys
            420                 425                 430

Ala Val Gly Gln Gly Cys Val Glu Ile Gly Ser Gln Arg Tyr Lys Leu
        435                 440                 445

Gly Val Arg Leu Tyr Tyr Arg Val Met Glu Ser Met Leu Lys Ser Glu
    450                 455                 460

Glu Glu Arg Leu Ser Ile Gln Asn Phe Ser Lys Leu Leu Asn Asp Asn
465                 470                 475                 480

Ile Phe His Met Ser Leu Leu Ala Cys Ala Leu Glu Val Val Met Ala
                485                 490                 495

Thr Tyr Ser Arg Ser Thr Ser Gln Asn Leu Asp Ser Gly Thr Asp Leu
            500                 505                 510
```

FIG. 2B

Ser Phe Pro Trp Ile Leu Asn Val Leu Asn Leu Lys Ala Phe Asp Phe
515 520 525

Tyr Lys Val Ile Glu Ser Phe Ile Lys Ala Glu Gly Asn Leu Thr Arg
530 535 540

Glu Met Ile Lys His Leu Glu Arg Cys Glu His Arg Ile Met Glu Ser
545 550 555 560

Leu Ala Trp Leu Ser Asp Ser Pro Leu Phe Asp Leu Ile Lys Gln Ser
565 570 575

Lys Asp Arg Glu Gly Pro Thr Asp His Leu Glu Ser Ala Cys Pro Leu
580 585 590

Asn Leu Pro Leu Gln Asn Asn His Thr Ala Ala Asp Met Tyr Leu Ser
595 600 605

Pro Val Arg Ser Pro Lys Lys Lys Gly Ser Thr Thr Arg Val Asn Ser
610 615 620

Thr Ala Asn Ala Glu Thr Gln Ala Thr Ser Ala Phe Gln Thr Gln Lys
625 630 635 640

Pro Leu Lys Ser Thr Ser Leu Ser Leu Phe Tyr Lys Lys Val Tyr Arg
645 650 655

Leu Ala Tyr Leu Arg Leu Asn Thr Leu Cys Glu Arg Leu Leu Ser Glu
660 665 670

His Pro Glu Leu Glu His Ile Ile Trp Thr Leu Phe Gln His Thr Leu
675 680 685

Gln Asn Glu Tyr Glu Leu Met Arg Asp Arg His Leu Asp Gln Ile Met
690 695 700

Met Cys Ser Met Tyr Gly Ile Cys Lys Val Lys Asn Ile Asp Leu Lys
705 710 715 720

Phe Lys Ile Ile Val Thr Ala Tyr Lys Asp Leu Pro His Ala Val Gln
725 730 735

Glu Thr Phe Lys Arg Val Leu Ile Lys Glu Glu Glu Tyr Asp Ser Ile
740 745 750

Ile Val Phe Tyr Asn Ser Val Phe Met Gln Arg Leu Lys Thr Asn Ile
755 760 765

FIG. 2C

```
Leu Gln Tyr Ala Ser Thr Arg Pro Pro Thr Leu Ser Pro Ile Pro His
    770                 775                 780

Ile Pro Arg Ser Pro Tyr Lys Phe Pro Ser Ser Pro Leu Arg Ile Pro
785                 790                 795                 800

Gly Gly Asn Ile Tyr Ile Ser Pro Leu Lys Ser Pro Tyr Lys Ile Ser
                805                 810                 815

Glu Gly Leu Pro Thr Pro Thr Lys Met Thr Pro Arg Ser Arg Ile Leu
            820                 825                 830

Val Ser Ile Gly Glu Ser Phe Gly Thr Ser Glu Lys Phe Gln Lys Ile
        835                 840                 845

Asn Gln Met Val Cys Asn Ser Asp Arg Val Leu Lys Arg Ser Ala Glu
    850                 855                 860

Gly Ser Asn Pro Pro Lys Pro Leu Lys Lys Leu Arg Phe Asp Ile Glu
865                 870                 875                 880

Gly Ser Asp Glu Ala Asp Gly Ser Lys His Leu Pro Gly Glu Ser Lys
                885                 890                 895

Phe Gln Gln Lys Leu Ala Glu Met Thr Ser Thr Arg Thr Arg Met Gln
            900                 905                 910

Lys Gln Lys Met Asn Asp Ser Met Asp Thr Ser Asn Lys Glu Glu Lys
        915                 920                 925
```

FIG. 2D

```
TTCCGGTTTT TCTCAGGGGA CGTTGAAATT ATTTTTGTAA CGGGAGTCGG GAGAGGACGG    60

GGCGTGCCCC GCGTGCGCGC GCGTCGTCCT CCCCGGCGCT CCTCCACAGC TCGCTGGCTC   120

CCGCCGCGGA AAGGCGTC ATG CCG CCC AAA ACC CCC CGA AAA ACG GCC GCC      171
                       Met Pro Pro Lys Thr Pro Arg Lys Thr Ala Ala
                         1               5                  10

ACC GCC GCC GCT GCC GCC GCG GAA CCC CCG GCA CCG CCG CCG CCG CCC      219
Thr Ala Ala Ala Ala Ala Ala Glu Pro Pro Ala Pro Pro Pro Pro Pro
               15                  20                  25

CCT CCT GAG GAG GAC CCA GAG CAG GAC AGC GGC CCG GAG GAC CTG CCT      267
Pro Pro Glu Glu Asp Pro Glu Gln Asp Ser Gly Pro Glu Asp Leu Pro
          30                  35                  40

CTC GTC AGG CTT GAG TTT GAA GAA ACA GAA GAA CCT GAT TTT ACT GCA      315
Leu Val Arg Leu Glu Phe Glu Glu Thr Glu Glu Pro Asp Phe Thr Ala
     45                  50                  55

TTA TGT CAG AAA TTA AAG ATA CCA GAT CAT GTC AGA GAG AGA GCT TGG      363
Leu Cys Gln Lys Leu Lys Ile Pro Asp His Val Arg Glu Arg Ala Trp
 60                  65                  70                  75

TTA ACT TGG GAG AAA GTT TCA TCT GTG GAT GGA GTA TTG GGA GGT TAT      411
Leu Thr Trp Glu Lys Val Ser Ser Val Asp Gly Val Leu Gly Gly Tyr
                 80                  85                  90

ATT CAA AAG AAA AAG GAA CTG TGG GGA ATC TGT ATC TTT ATT GCA GCA      459
Ile Gln Lys Lys Lys Glu Leu Trp Gly Ile Cys Ile Phe Ile Ala Ala
               95                 100                 105

GTT GAC CTA GAT GAG ATG TCG TTC ACT TTT ACT GAG CTA CAG AAA AAC      507
Val Asp Leu Asp Glu Met Ser Phe Thr Phe Thr Glu Leu Gln Lys Asn
          110                 115                 120

ATA GAA ATC AGT GTC CAT AAA TTC TTT AAC TTA CTA AAA GAA ATT GAT      555
Ile Glu Ile Ser Val His Lys Phe Phe Asn Leu Leu Lys Glu Ile Asp
     125                 130                 135

ACC AGT ACC AAA GTT GAT AAT GCT ATG TCA AGA CTG TTG AAG AAG TAT      603
Thr Ser Thr Lys Val Asp Asn Ala Met Ser Arg Leu Leu Lys Lys Tyr
140                 145                 150                 155

GAT GTA TTG TTT GCA CTC TTC AGC AAA TTG GAA AGG ACA TGT GAA CTT      651
Asp Val Leu Phe Ala Leu Phe Ser Lys Leu Glu Arg Thr Cys Glu Leu
                160                 165                 170

ATA TAT TTG ACA CAA CCC AGC AGT TCG ATA TCT ACT GAA ATA AAT TCT      699
Ile Tyr Leu Thr Gln Pro Ser Ser Ser Ile Ser Thr Glu Ile Asn Ser
               175                 180                 185

GCA TTG GTG CTA AAA GTT TCT TGG ATC ACA TTT TTA TTA GCT AAA GGG      747
Ala Leu Val Leu Lys Val Ser Trp Ile Thr Phe Leu Leu Ala Lys Gly
          190                 195                 200

GAA GTA TTA CAA ATG GAA GAT GAT CTG GTG ATT TCA TTT CAG TTA ATG      795
Glu Val Leu Gln Met Glu Asp Asp Leu Val Ile Ser Phe Gln Leu Met
     205                 210                 215
```

FIG. 3A

```
CTA TGT GTC CTT GAC TAT TTT ATT AAA CTC TCA CCT CCC ATG TTG CTC    843
Leu Cys Val Leu Asp Tyr Phe Ile Lys Leu Ser Pro Pro Met Leu Leu
220                 225                 230                 235

AAA GAA CCA TAT AAA ACA GCT GTT ATA CCC ATT AAT GGT TCA CCT CGA    891
Lys Glu Pro Tyr Lys Thr Ala Val Ile Pro Ile Asn Gly Ser Pro Arg
                240                 245                 250

ACA CCC AGG CGA GGT CAG AAC AGG AGT GCA CGG ATA GCA AAA CAA CTA    939
Thr Pro Arg Arg Gly Gln Asn Arg Ser Ala Arg Ile Ala Lys Gln Leu
            255                 260                 265

GAA AAT GAT ACA AGA ATT ATT GAA GTT CTC TGT AAA GAA CAT GAA TGT    987
Glu Asn Asp Thr Arg Ile Ile Glu Val Leu Cys Lys Glu His Glu Cys
        270                 275                 280

AAT ATA GAT GAG GTG AAA AAT GTT TAT TTC AAA AAT TTT ATA CCT TTT   1035
Asn Ile Asp Glu Val Lys Asn Val Tyr Phe Lys Asn Phe Ile Pro Phe
    285                 290                 295

ATG AAT TCT CTT GGA CTT GTA ACA TCT AAT GGA CTT CCA GAG GTT GAA   1083
Met Asn Ser Leu Gly Leu Val Thr Ser Asn Gly Leu Pro Glu Val Glu
300                 305                 310                 315

AAT CTT TCT AAA CGA TAC GAA GAA ATT TAT CTT AAA AAT AAA GAT CTA   1131
Asn Leu Ser Lys Arg Tyr Glu Glu Ile Tyr Leu Lys Asn Lys Asp Leu
                320                 325                 330

GAT GCA AGA TTA TTT TTG GAT CAT GAT AAA ACT CTT CAG ACT GAT TCT   1179
Asp Ala Arg Leu Phe Leu Asp His Asp Lys Thr Leu Gln Thr Asp Ser
            335                 340                 345

ATA GAC AGT TTT GAA ACA CAG AGA ACA CCA CGA AAA AGT AAC CTT GAT   1227
Ile Asp Ser Phe Glu Thr Gln Arg Thr Pro Arg Lys Ser Asn Leu Asp
        350                 355                 360

GAA GAG GTG AAT GTA ATT CCT CCA CAC ACT CCA GTT AGG ACT GTT ATG   1275
Glu Glu Val Asn Val Ile Pro Pro His Thr Pro Val Arg Thr Val Met
    365                 370                 375

AAC ACT ATC CAA CAA TTA ATG ATG ATT TTA AAT TCA GCA AGT GAT CAA   1323
Asn Thr Ile Gln Gln Leu Met Met Ile Leu Asn Ser Ala Ser Asp Gln
380                 385                 390                 395

CCT TCA GAA AAT CTG ATT TCC TAT TTT AAC AAC TGC ACA GTG AAT CCA   1371
Pro Ser Glu Asn Leu Ile Ser Tyr Phe Asn Asn Cys Thr Val Asn Pro
                400                 405                 410

AAA GAA AGT ATA CTG AAA AGA GTG AAG GAT ATA GGA TAC ATC TTT AAA   1419
Lys Glu Ser Ile Leu Lys Arg Val Lys Asp Ile Gly Tyr Ile Phe Lys
            415                 420                 425

GAG AAA TTT GCT AAA GCT GTG GGA CAG GGT TGT GTC GAA ATT GGA TCA   1467
Glu Lys Phe Ala Lys Ala Val Gly Gln Gly Cys Val Glu Ile Gly Ser
        430                 435                 440

CAG CGA TAC AAA CTT GGA GTT CGC TTG TAT TAC CGA GTA ATG GAA TCC   1515
Gln Arg Tyr Lys Leu Gly Val Arg Leu Tyr Tyr Arg Val Met Glu Ser
    445                 450                 455
```

FIG. 3B

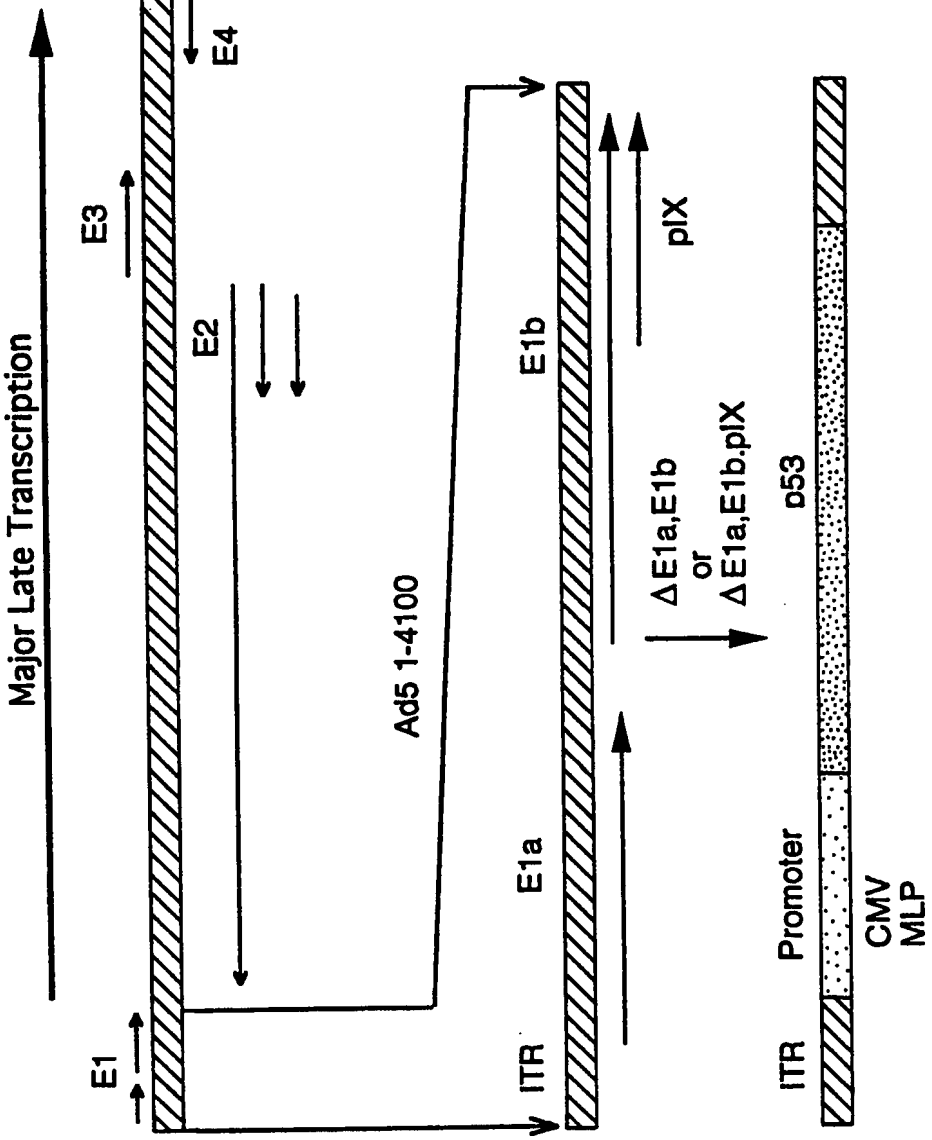
```
ATG CTT AAA TCA GAA GAA GAA CGA TTA TCC ATT CAA AAT TTT AGC AAA  1563
Met Leu Lys Ser Glu Glu Glu Arg Leu Ser Ile Gln Asn Phe Ser Lys
460                 465                 470                 475

CTT CTG AAT GAC AAC ATT TTT CAT ATG TCT TTA TTG GCG TGC GCT CTT  1611
Leu Leu Asn Asp Asn Ile Phe His Met Ser Leu Leu Ala Cys Ala Leu
                480                 485                 490

GAG GTT GTA ATG GCC ACA TAT AGC AGA AGT ACA TCT CAG AAT CTT GAT  1659
Glu Val Val Met Ala Thr Tyr Ser Arg Ser Thr Ser Gln Asn Leu Asp
            495                 500                 505

TCT GGA ACA GAT TTG TCT TTC CCA TGG ATT CTG AAT GTG CTT AAT TTA  1707
Ser Gly Thr Asp Leu Ser Phe Pro Trp Ile Leu Asn Val Leu Asn Leu
        510                 515                 520

AAA GCC TTT GAT TTT TAC AAA GTG ATC GAA AGT TTT ATC AAA GCA GAA  1755
Lys Ala Phe Asp Phe Tyr Lys Val Ile Glu Ser Phe Ile Lys Ala Glu
    525                 530                 535

GGC AAC TTG ACA AGA GAA ATG ATA AAA CAT TTA GAA CGA TGT GAA CAT  1803
Gly Asn Leu Thr Arg Glu Met Ile Lys His Leu Glu Arg Cys Glu His
540                 545                 550                 555

CGA ATC ATG GAA TCC CTT GCA TGG CTC TCA GAT TCA CCT TTA TTT GAT  1851
Arg Ile Met Glu Ser Leu Ala Trp Leu Ser Asp Ser Pro Leu Phe Asp
                560                 565                 570

CTT ATT AAA CAA TCA AAG GAC CGA GAA GGA CCA ACT GAT CAC CTT GAA  1899
Leu Ile Lys Gln Ser Lys Asp Arg Glu Gly Pro Thr Asp His Leu Glu
            575                 580                 585

TCT GCT TGT CCT CTT AAT CTT CCT CTC CAG AAT AAT CAC ACT GCA GCA  1947
Ser Ala Cys Pro Leu Asn Leu Pro Leu Gln Asn Asn His Thr Ala Ala
        590                 595                 600

GAT ATG TAT CTT TCT CCT GTA AGA TCT CCA AAG AAA AAA GGT TCA ACT  1995
Asp Met Tyr Leu Ser Pro Val Arg Ser Pro Lys Lys Lys Gly Ser Thr
    605                 610                 615

ACG CGT GTA AAT TCT ACT GCA AAT GCA GAG ACA CAA GCA ACC TCA GCC  2043
Thr Arg Val Asn Ser Thr Ala Asn Ala Glu Thr Gln Ala Thr Ser Ala
620                 625                 630                 635

TTC CAG ACC CAG AAG CCA TTG AAA TCT ACC TCT CTT TCA CTG TTT TAT  2091
Phe Gln Thr Gln Lys Pro Leu Lys Ser Thr Ser Leu Ser Leu Phe Tyr
                640                 645                 650

AAA AAA GTG TAT CGG CTA GCC TAT CTC CGG CTA AAT ACA CTT TGT GAA  2139
Lys Lys Val Tyr Arg Leu Ala Tyr Leu Arg Leu Asn Thr Leu Cys Glu
            655                 660                 665

CGC CTT CTG TCT GAG CAC CCA GAA TTA GAA CAT ATC ATC TGG ACC CTT  2187
Arg Leu Leu Ser Glu His Pro Glu Leu Glu His Ile Ile Trp Thr Leu
        670                 675                 680

TTC CAG CAC ACC CTG CAG AAT GAG TAT GAA CTC ATG AGA GAC AGG CAT  2235
Phe Gln His Thr Leu Gln Asn Glu Tyr Glu Leu Met Arg Asp Arg His
    685                 690                 695
```

FIG. 3C

```
TTG GAC CAA ATT ATG ATG TGT TCC ATG TAT GGC ATA TGC AAA GTG AAG  2283
Leu Asp Gln Ile Met Met Cys Ser Met Tyr Gly Ile Cys Lys Val Lys
700                 705                 710                 715

AAT ATA GAC CTT AAA TTC AAA ATC ATT GTA ACA GCA TAC AAG GAT CTT  2331
Asn Ile Asp Leu Lys Phe Lys Ile Ile Val Thr Ala Tyr Lys Asp Leu
                720                 725                 730

CCT CAT GCT GTT CAG GAG ACA TTC AAA CGT GTT TTG ATC AAA GAA GAG  2379
Pro His Ala Val Gln Glu Thr Phe Lys Arg Val Leu Ile Lys Glu Glu
            735                 740                 745

GAG TAT GAT TCT ATT ATA GTA TTC TAT AAC TCG GTC TTC ATG CAG AGA  2427
Glu Tyr Asp Ser Ile Ile Val Phe Tyr Asn Ser Val Phe Met Gln Arg
        750                 755                 760

CTG AAA ACA AAT ATT TTG CAG TAT GCT TCC ACC AGG CCC CCT ACC TTG  2475
Leu Lys Thr Asn Ile Leu Gln Tyr Ala Ser Thr Arg Pro Pro Thr Leu
    765                 770                 775

TCA CCA ATA CCT CAC ATT CCT CGA AGC CCT TAC AAG TTT CCT AGT TCA  2523
Ser Pro Ile Pro His Ile Pro Arg Ser Pro Tyr Lys Phe Pro Ser Ser
780                 785                 790                 795

CCC TTA CGG ATT CCT GGA GGG AAC ATC TAT ATT TCA CCC CTG AAG AGT  2571
Pro Leu Arg Ile Pro Gly Gly Asn Ile Tyr Ile Ser Pro Leu Lys Ser
                800                 805                 810

CCA TAT AAA ATT TCA GAA GGT CTG CCA ACA CCA ACA AAA ATG ACT CCA  2619
Pro Tyr Lys Ile Ser Glu Gly Leu Pro Thr Pro Thr Lys Met Thr Pro
            815                 820                 825

AGA TCA AGA ATC TTA GTA TCA ATT GGT GAA TCA TTC GGG ACT TCT GAG  2667
Arg Ser Arg Ile Leu Val Ser Ile Gly Glu Ser Phe Gly Thr Ser Glu
        830                 835                 840

AAG TTC CAG AAA ATA AAT CAG ATG GTA TGT AAC AGC GAC CGT GTG CTC  2715
Lys Phe Gln Lys Ile Asn Gln Met Val Cys Asn Ser Asp Arg Val Leu
    845                 850                 855

AAA AGA AGT GCT GAA GGA AGC AAC CCT CCT AAA CCA CTG AAA AAA CTA  2763
Lys Arg Ser Ala Glu Gly Ser Asn Pro Pro Lys Pro Leu Lys Lys Leu
860                 865                 870                 875

CGC TTT GAT ATT GAA GGA TCA GAT GAA GCA GAT GGA AGT AAA CAT CTC  2811
Arg Phe Asp Ile Glu Gly Ser Asp Glu Ala Asp Gly Ser Lys His Leu
                880                 885                 890

CCA GGA GAG TCC AAA TTT CAG CAG AAA CTG GCA GAA ATG ACT TCT ACT  2859
Pro Gly Glu Ser Lys Phe Gln Gln Lys Leu Ala Glu Met Thr Ser Thr
            895                 900                 905

CGA ACA CGA ATG CAA AAG CAG AAA ATG AAT GAT AGC ATG GAT ACC TCA  2907
Arg Thr Arg Met Gln Lys Gln Lys Met Asn Asp Ser Met Asp Thr Ser
        910                 915                 920

AAC AAG GAA GAG AAA TGAGGATCTC AGGACCTTGG TGGACACTGT GTACACCTCT  2962
Asn Lys Glu Glu Lys
    925

GGATTCATTG TCTCTCACAG ATGTGACTGA TAT                             2995
```

FIG. 3D

FIG. 4


Ad 5
Major Late Transcription
E1
E2
E3
E4
ITR
E1a
E1b
Ad5 1-4100
pIX
ΔE1a,E1b
or
ΔE1a,E1b.pIX
p53
Promoter
CMV
MLP
ITR

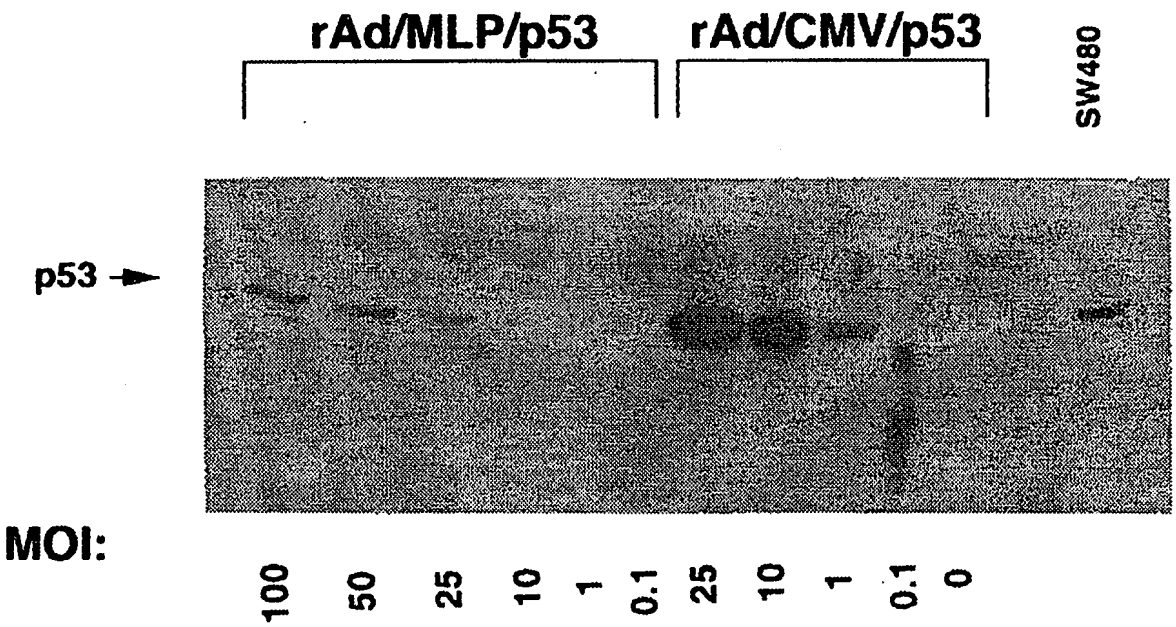

rAd/MLP/p53
rAd/CMV/p53
SW480
p53
MOI:
100 50 25 10 1 0.1 25 10 1 0.1 0

FIG. 5A

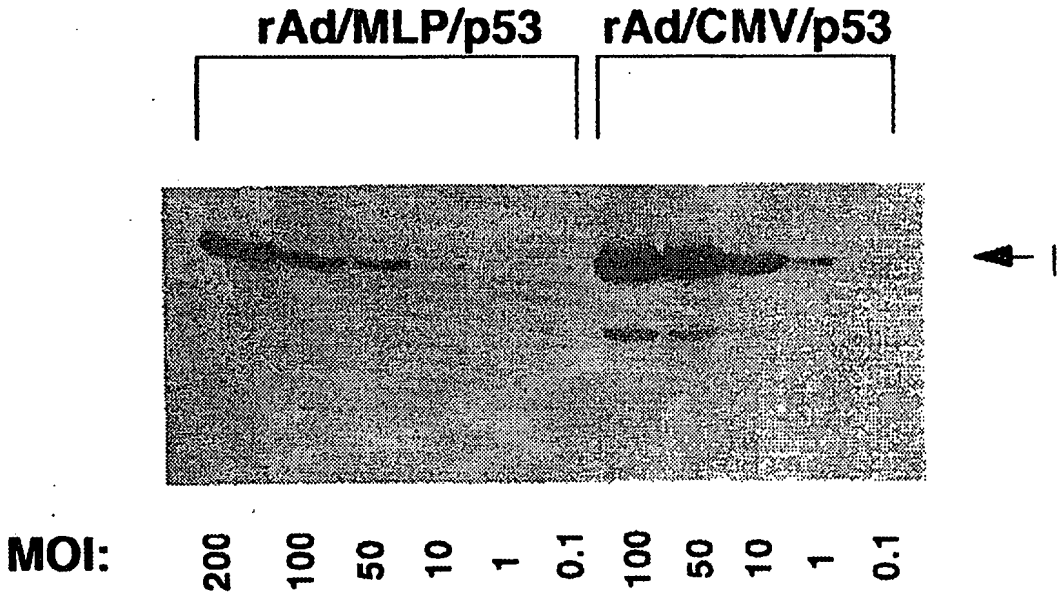

rAd/MLP/p53
rAd/CMV/p53
MOI:
200 100 50 10 1 0.1 100 50 10 1 0.1

FIG. 5B

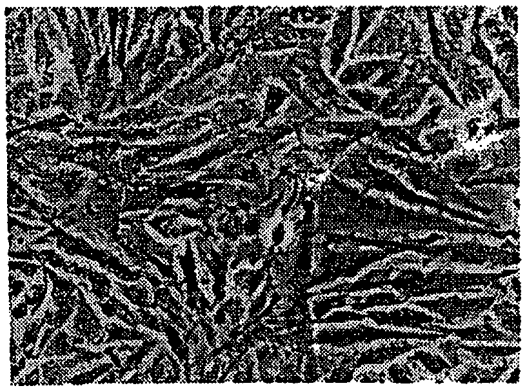


FIG. 6A

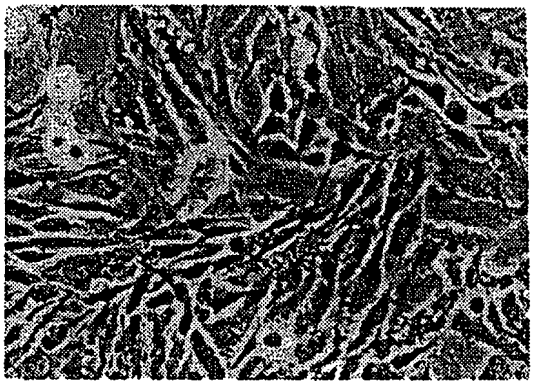


FIG. 6B

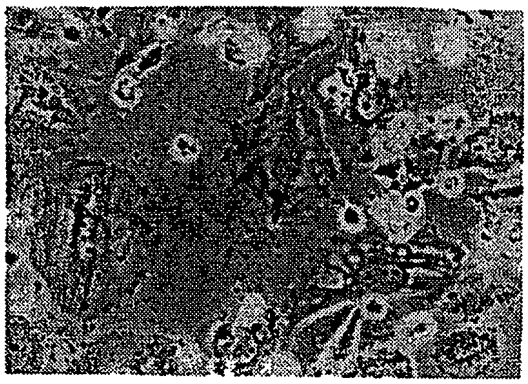


FIG. 6C

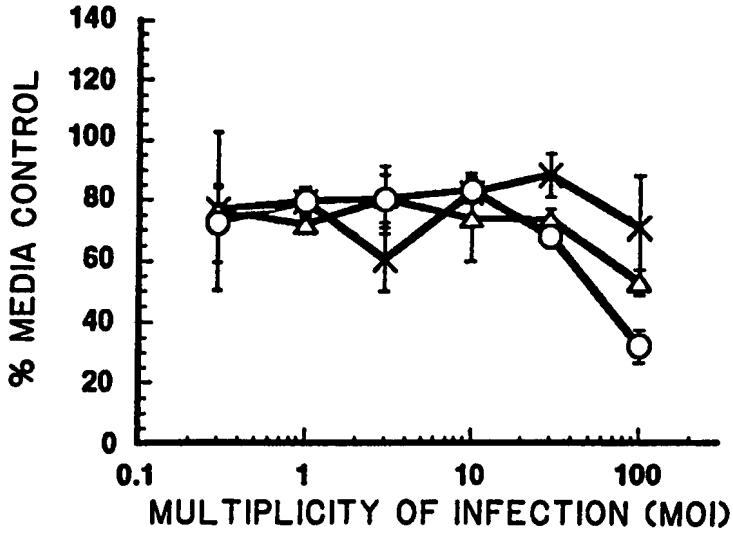


FIG. 7A

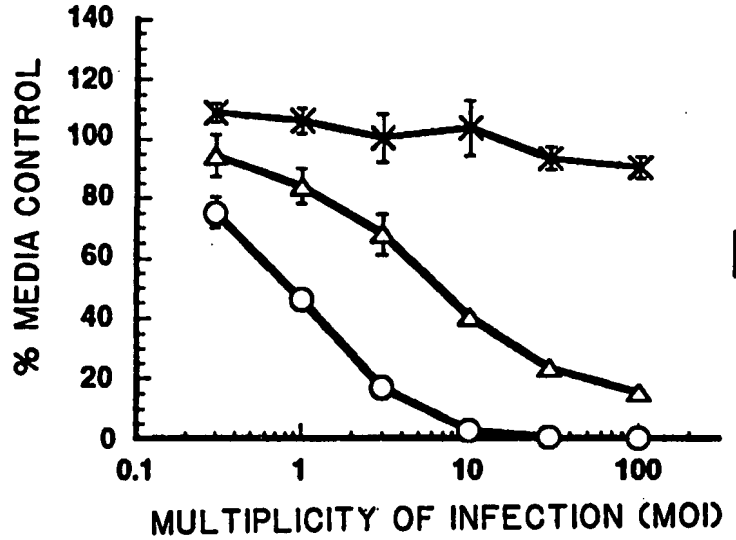


FIG. 7B

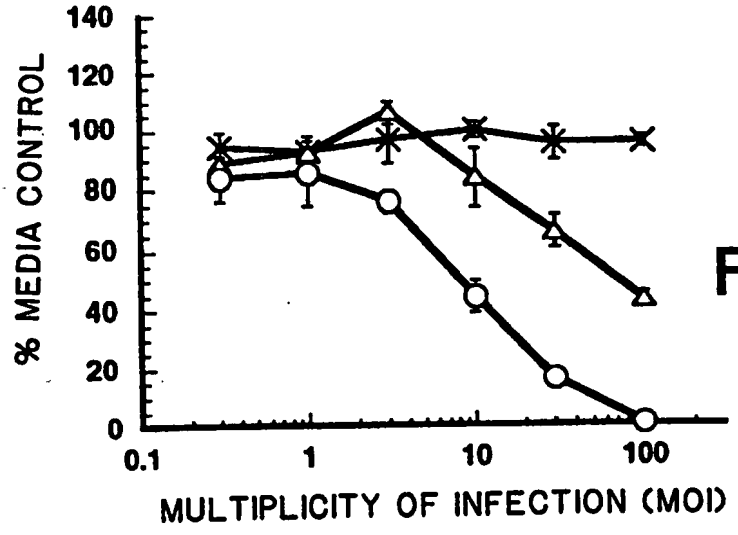


FIG. 7C

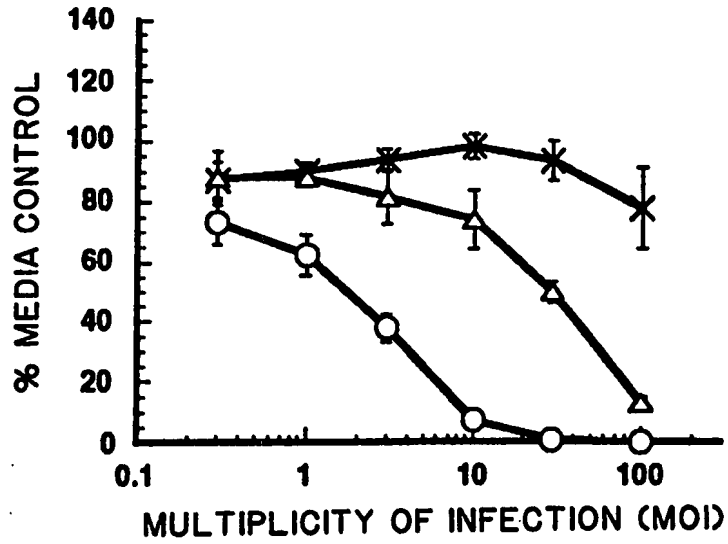


FIG. 7D

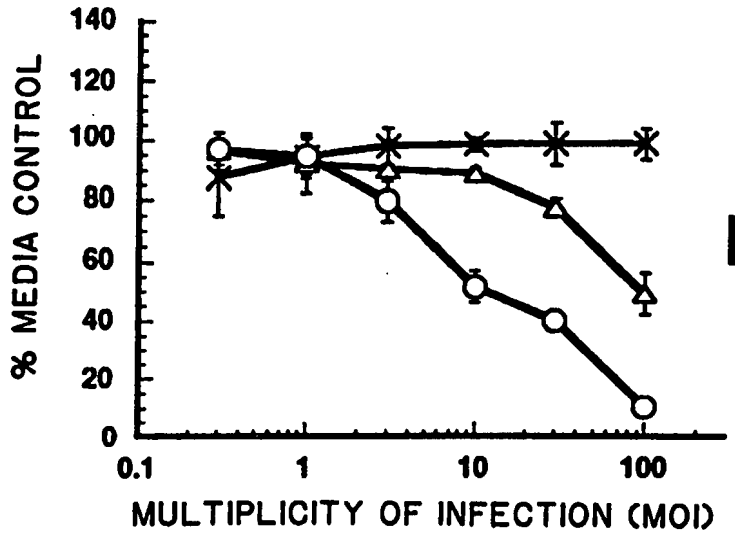


FIG. 7E

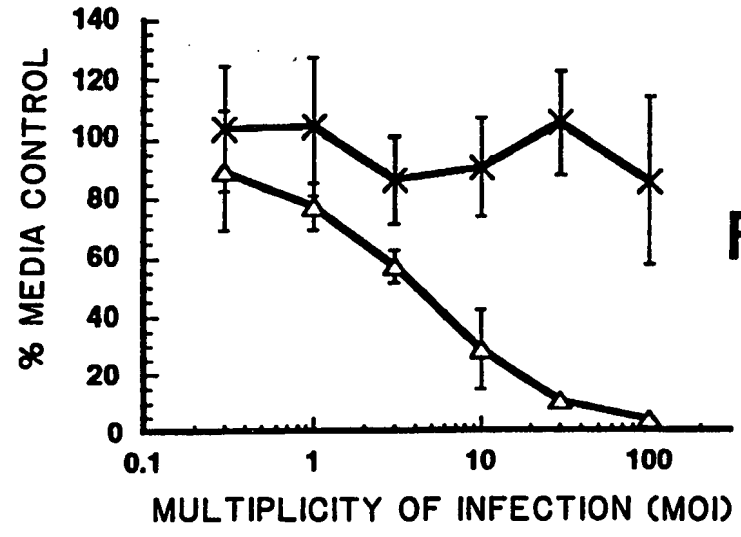


FIG. 7F

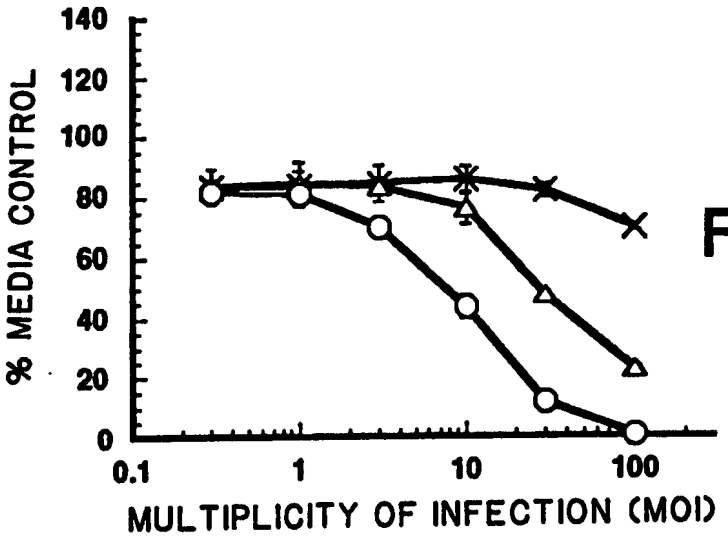


FIG. 7G

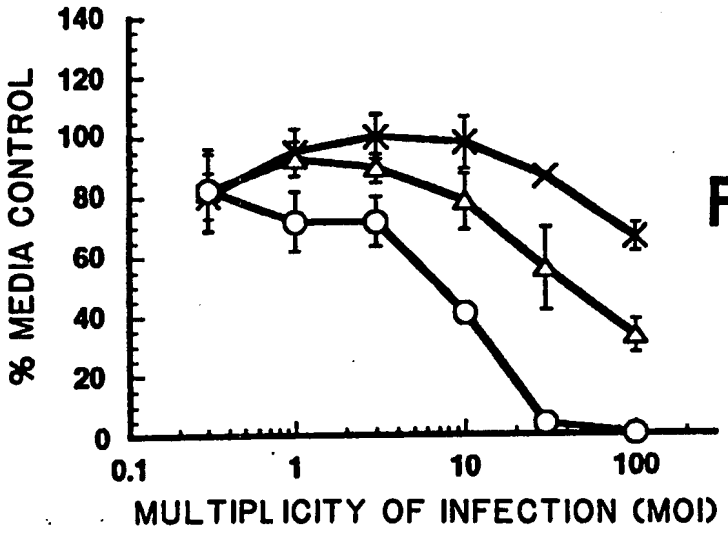


FIG. 7H

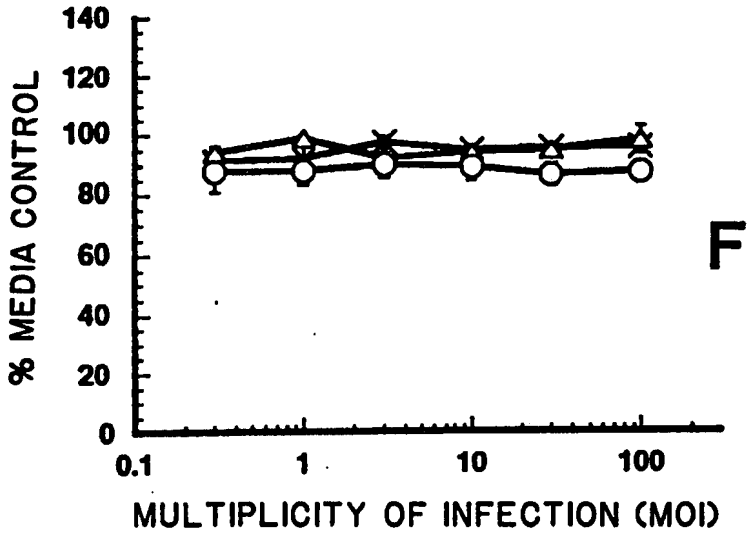


FIG. 7I

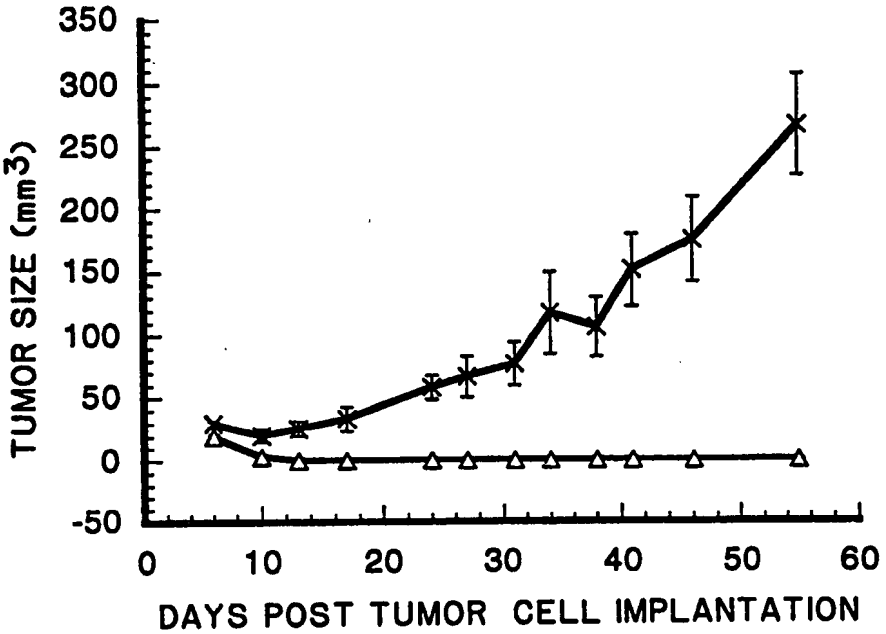

350
300
250
200
150
100
50
0
-50
TUMOR SIZE (mm3)
0
10
20
30
40
50
60
DAYS POST TUMOR CELL IMPLANTATION

FIG. 8

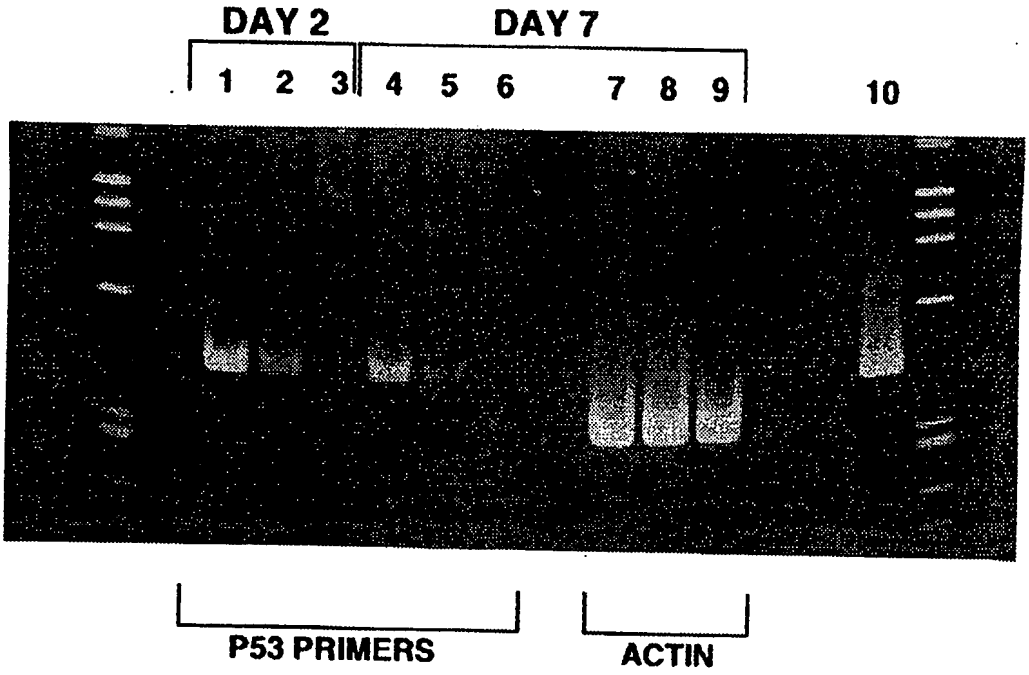


FIG. 9

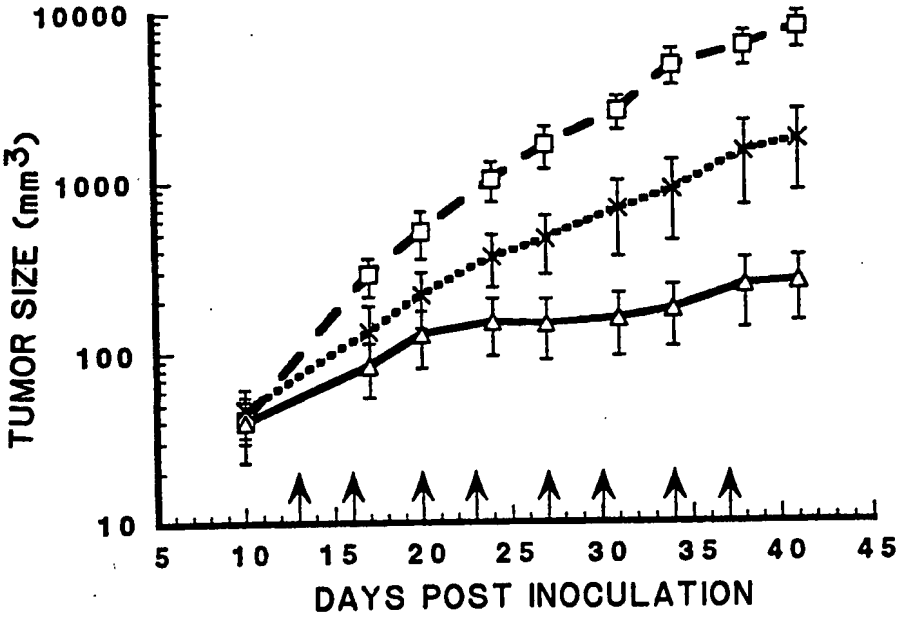


FIG. 10A

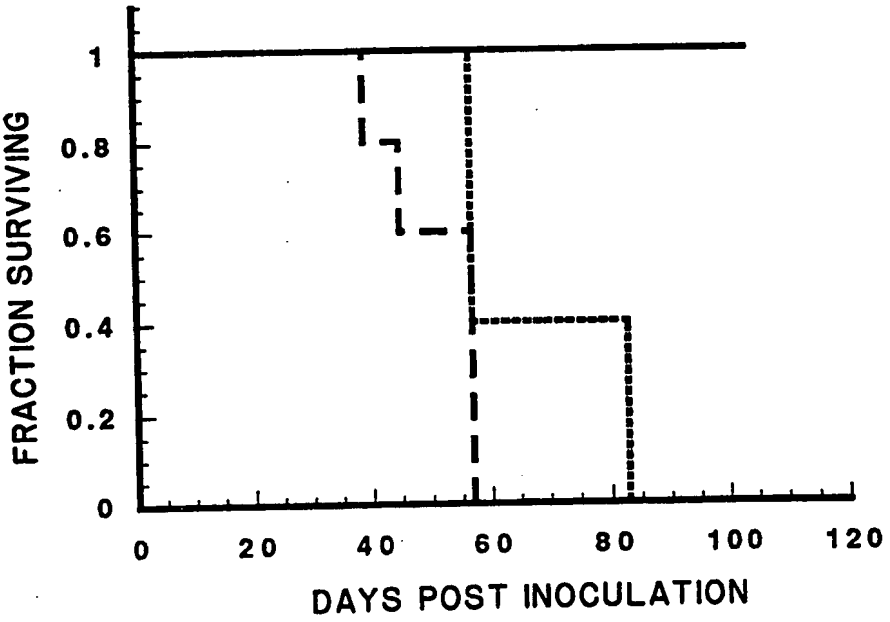


FIG. 10B

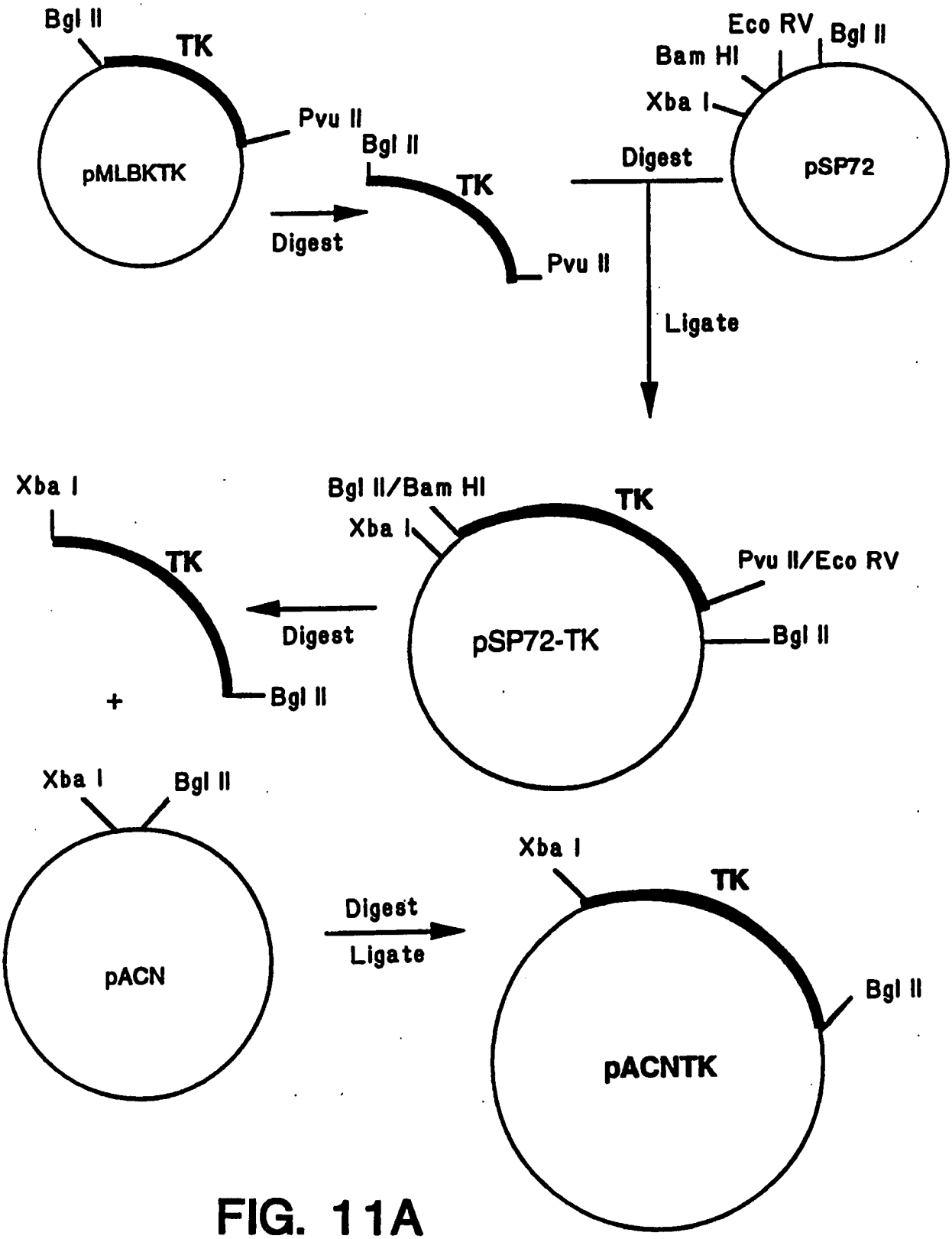
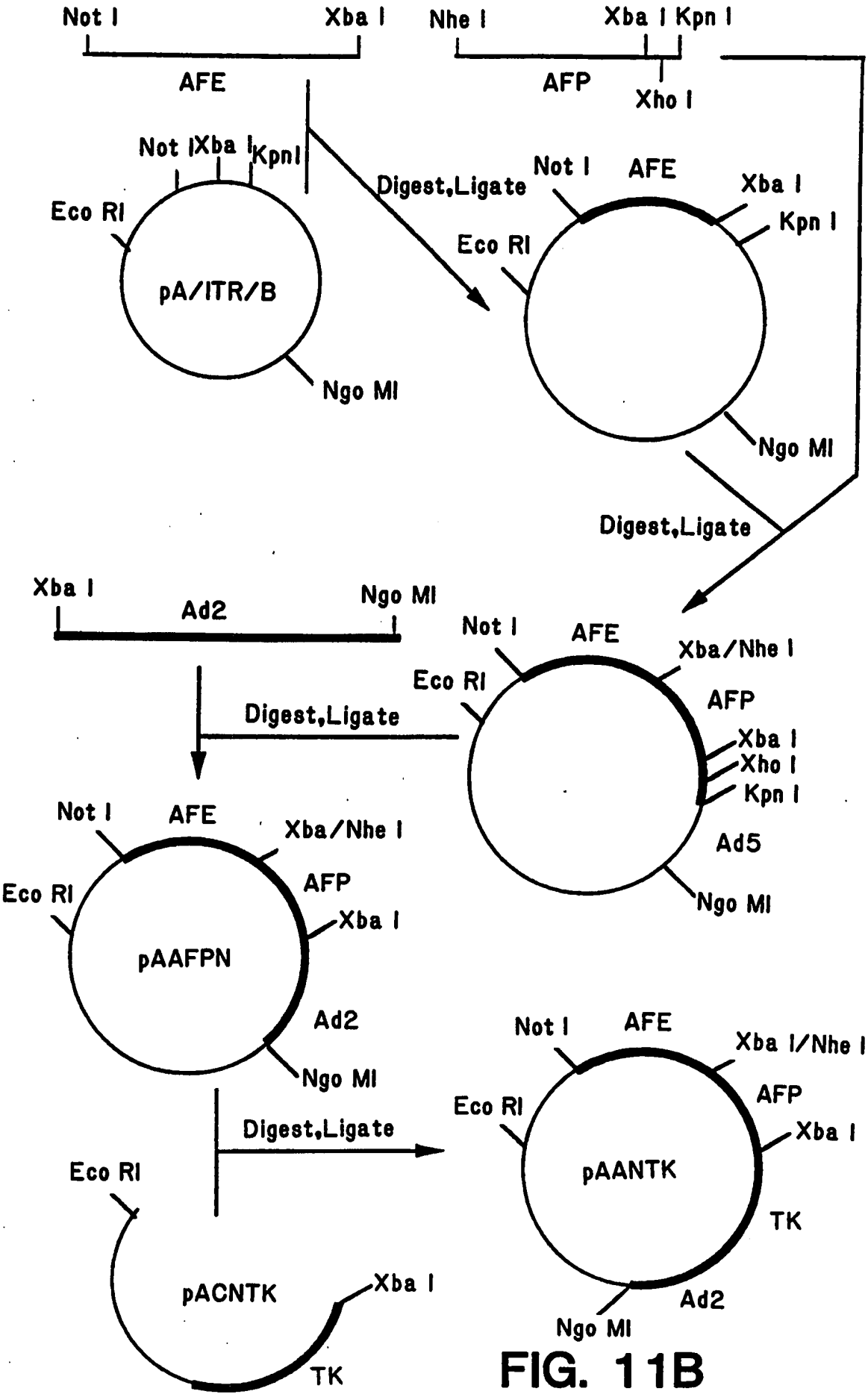

Bgl II
TK
Pvu II
pMLBKTK
Digest
Bgl II
TK
Pvu II
Eco RV
Bgl II
Bam HI
Xba I
Digest
pSP72
Ligate
Xba I
TK
Digest
Bgl II
+
Bgl II/Bam HI
Xba I
TK
Pvu II/Eco RV
pSP72-TK
Bgl II
Xba I
Bgl II
pACN
Digest
Ligate
Xba I
TK
Bgl II
pACNTK

FIG. 11A


Not I
Xba I
AFE
Nhe I
Xba I Kpn I
AFP
Xho I
Not I Xba I Kpn I
Eco RI
pA/ITR/B
Ngo MI
Digest,Ligate
Not I
AFE
Xba I
Kpn I
Eco RI
Ngo MI
Digest,Ligate
Xba I
Ad2
Ngo MI
Not I
AFE
Xba/Nhe I
Eco RI
AFP
Xba I
Xho I
Kpn I
Ad5
Ngo MI
Digest,Ligate
Not I
AFE
Xba/Nhe I
Eco RI
AFP
Xba I
pAAFPN
Ad2
Ngo MI
Not I
AFE
Xba I/Nhe I
Eco RI
AFP
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TK
Ad2
Ngo MI
Digest,Ligate
Eco RI
pACNTK
Xba I
TK

FIG. 11B

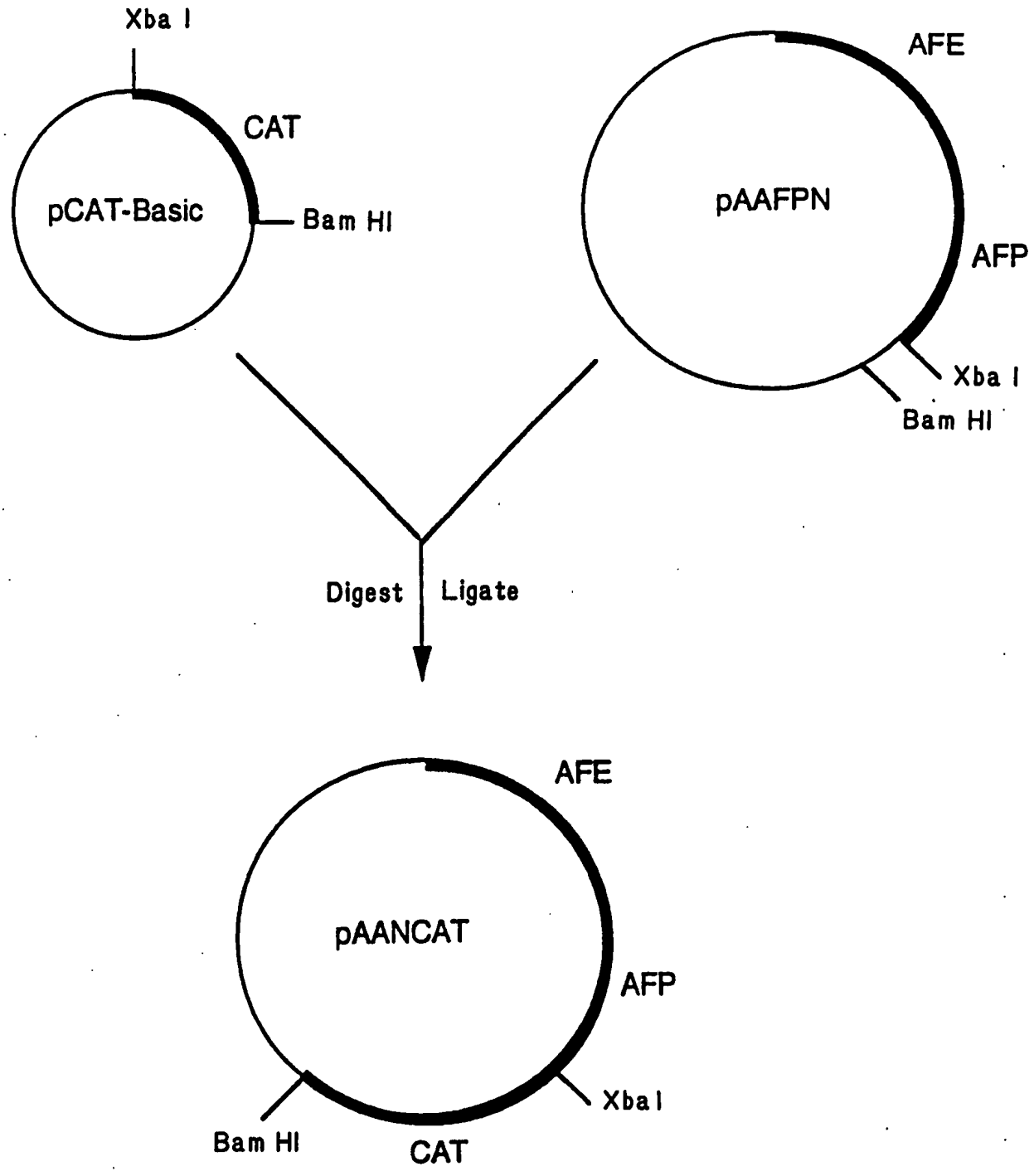
Xba I
CAT
pCAT-Basic
Bam HI
AFE
pAAFPN
AFP
Xba I
Bam HI
Digest
Ligate
AFE
pAANCAT
AFP
Xba I
Bam HI
CAT

FIG. 11C

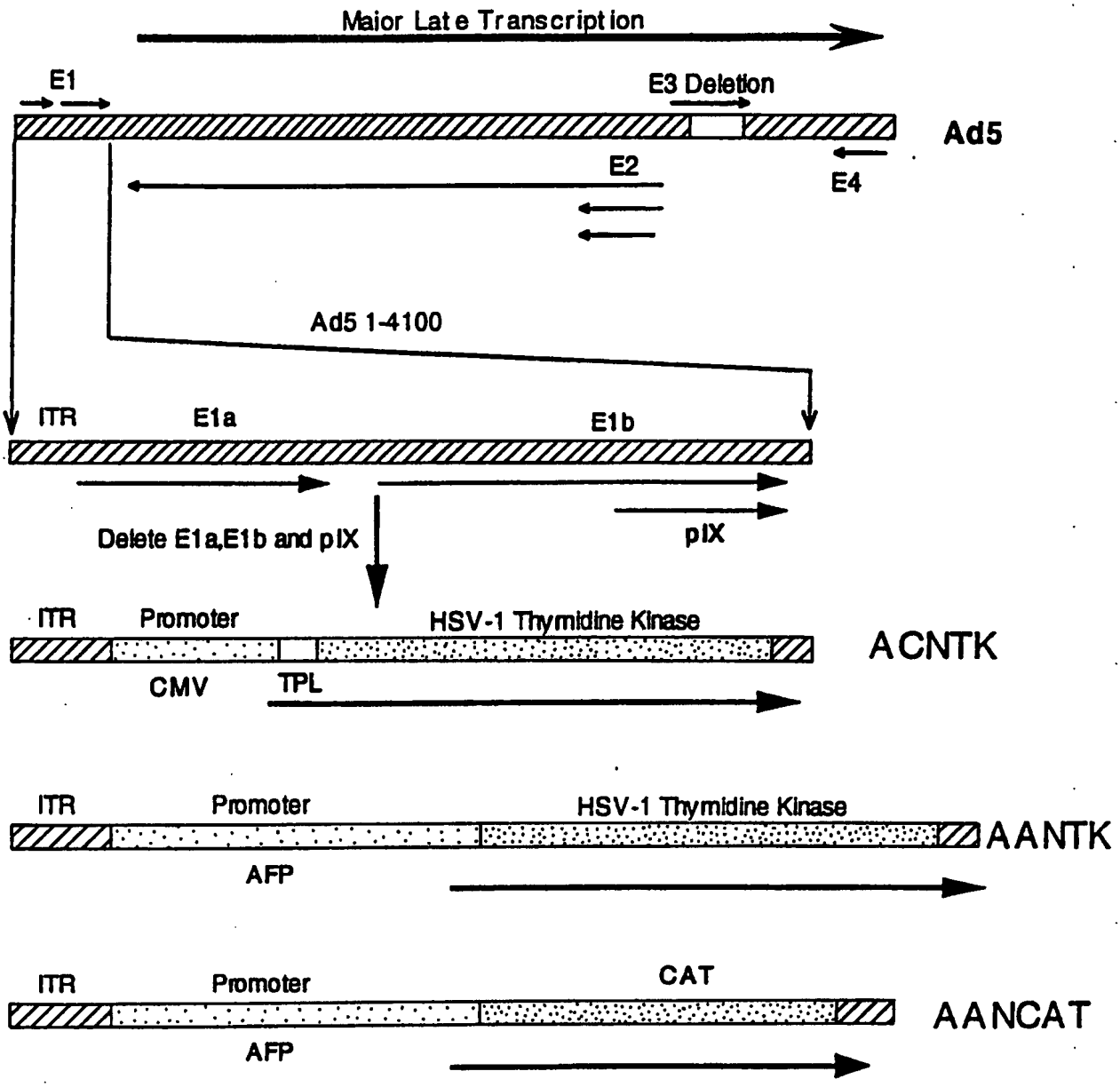
Major Late Transcription
E1
E3 Deletion
Ad5
E2
E4
Ad5 1-4100
ITR
E1a
E1b
Delete E1a,E1b and pIX
pIX
ITR
Promoter
HSV-1 Thymidine Kinase
ACNTK
CMV
TPL
ITR
Promoter
HSV-1 Thymidine Kinase
AANTK
AFP
ITR
Promoter
CAT
AANCAT
AFP

FIG. 12

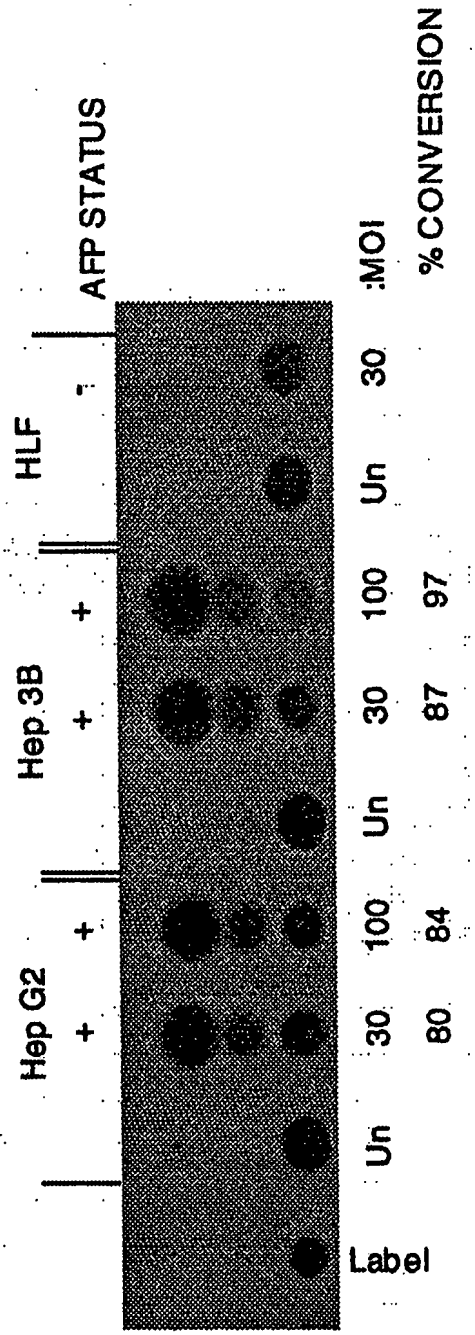

FIG. 13A

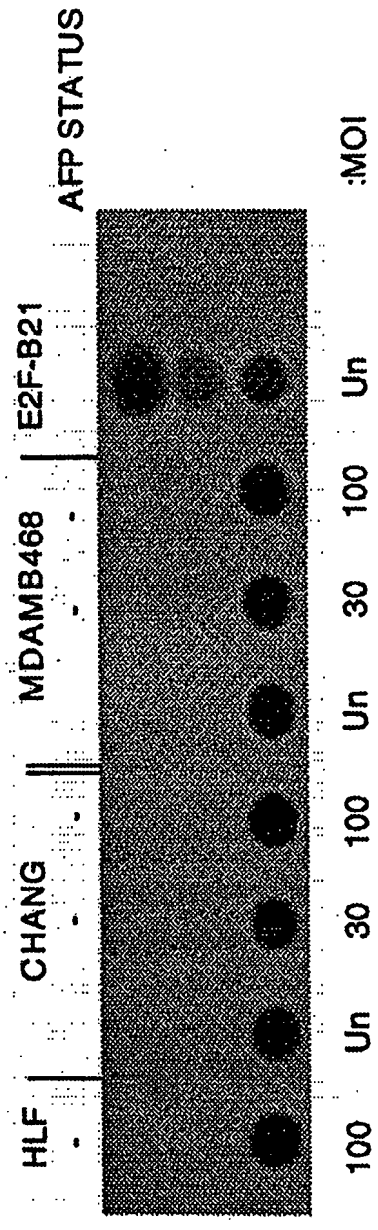

FIG. 13B

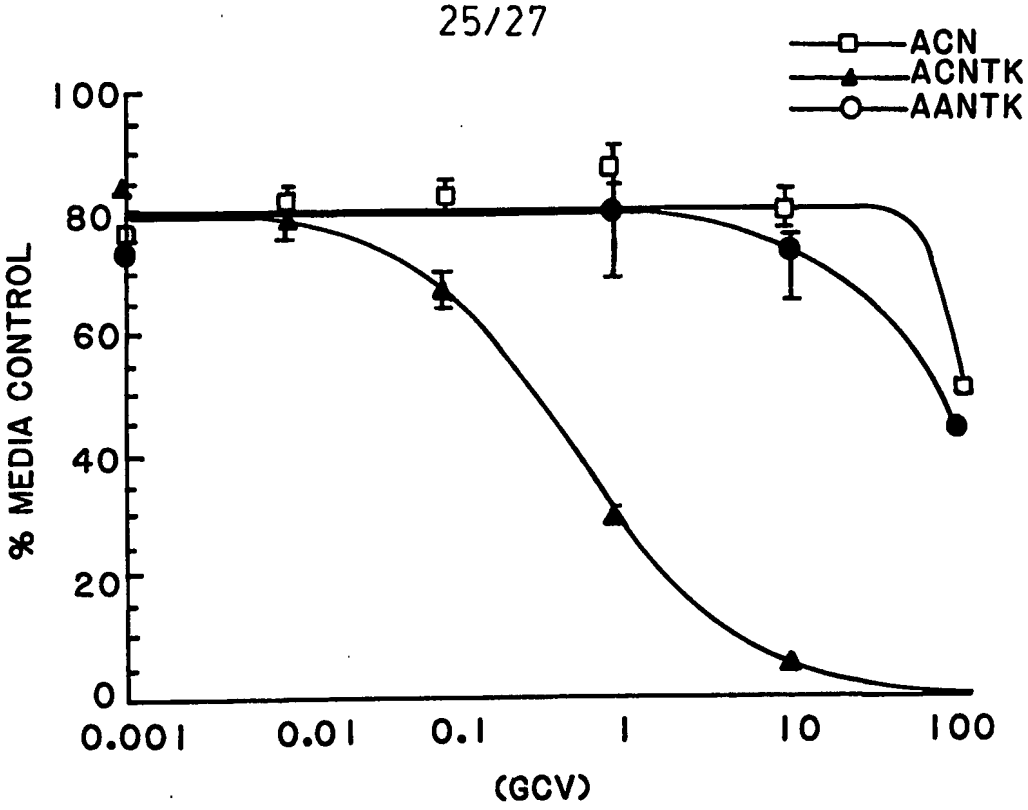

FIG. 14A

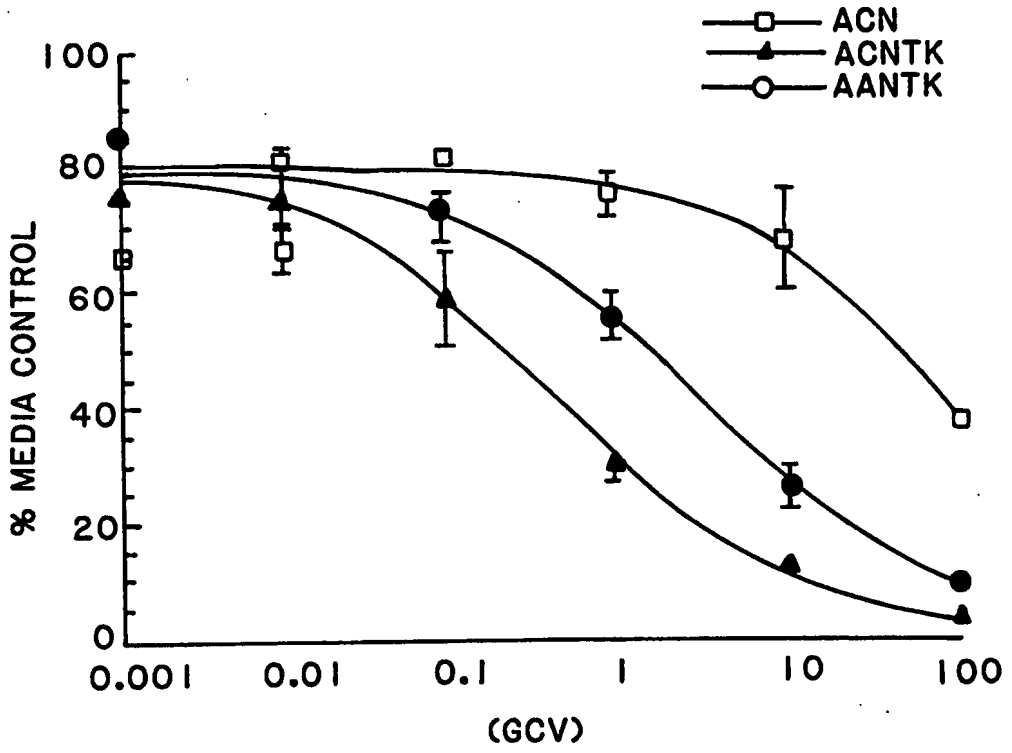

FIG. 14B

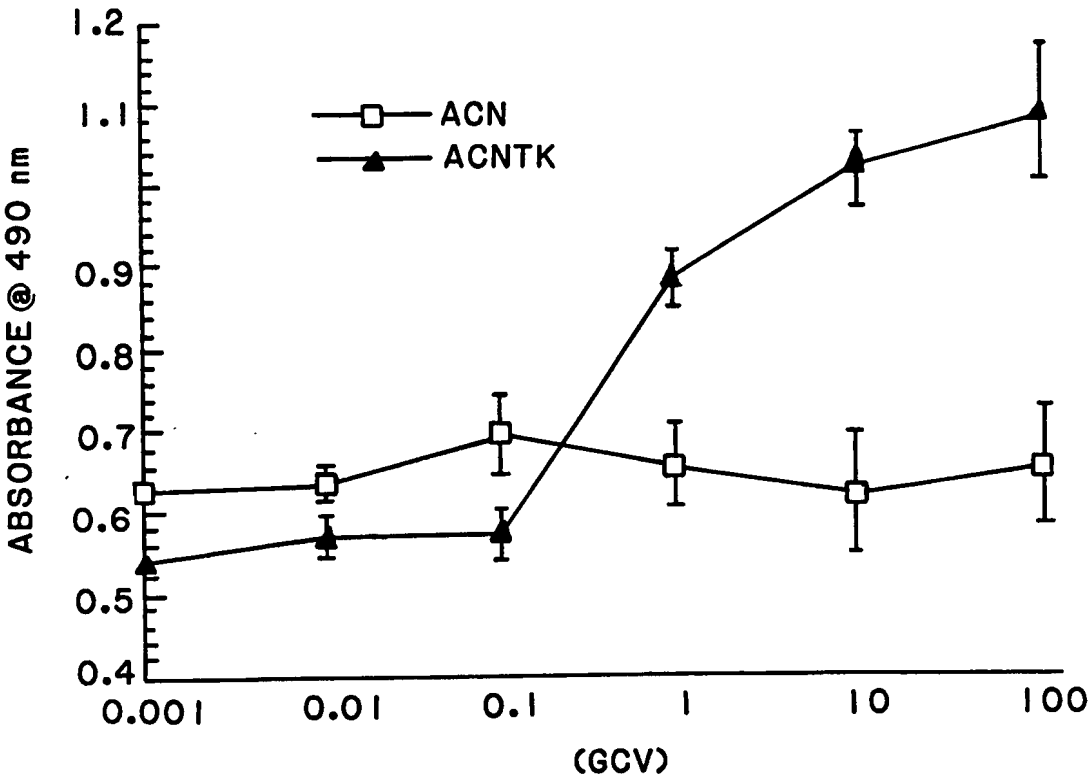
1.2
1.1
0.9
0.8
0.7
0.6
0.5
0.4
ABSORBANCE @ 490 nm
ACN
ACNTK
0.001
0.01
0.1
1
10
100
(GCV)

FIG. 15

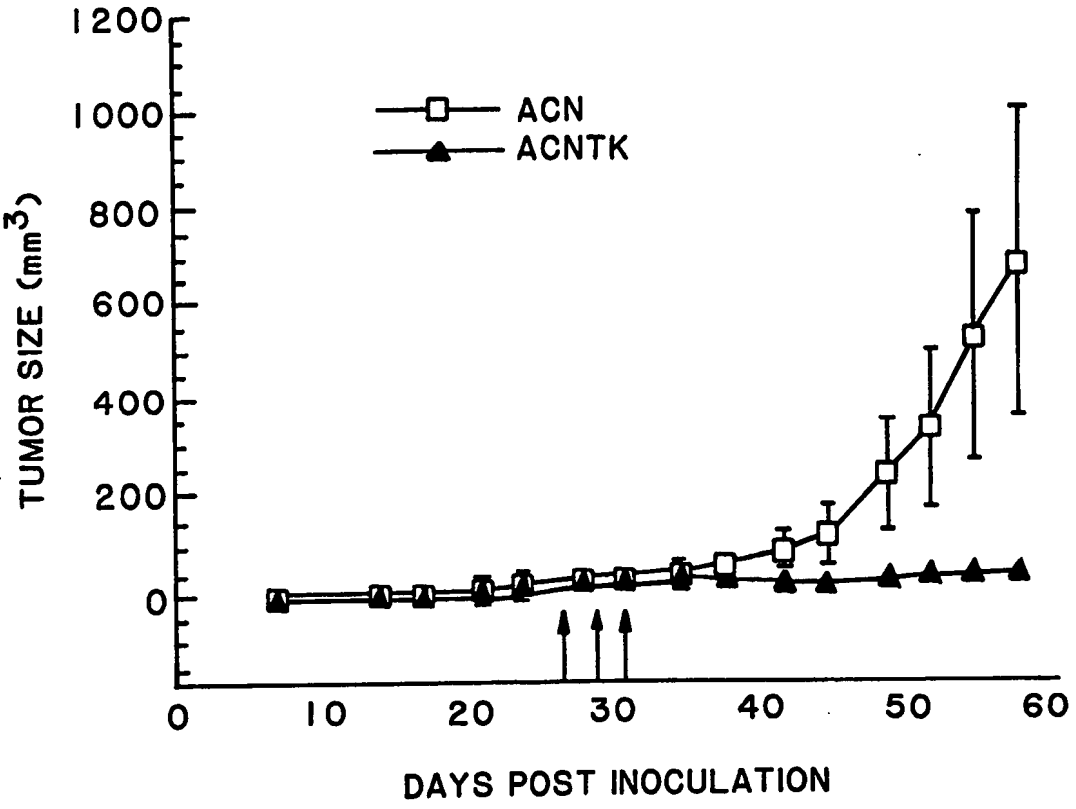

FIG. 16A

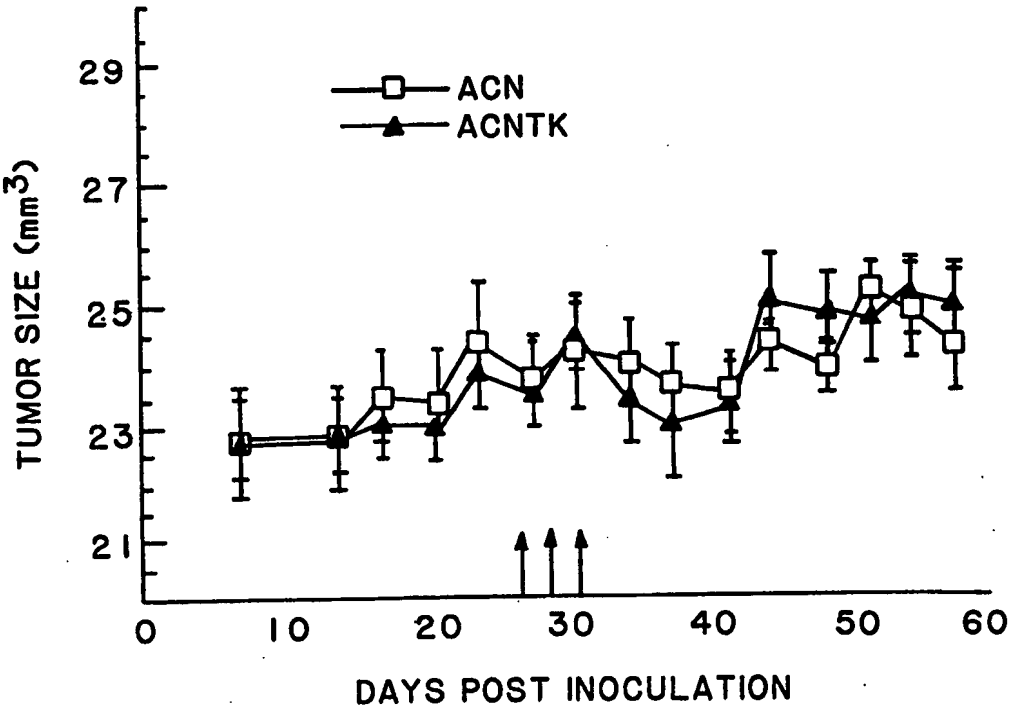

FIG. 16B

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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C12N 15/86, 7/01, 5/10, A61K 48/00, C07K 14/47

A3

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08/246,007	19 May 1994 (19.05.94)	US

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(74) Agents: STEINHARDT, Paul, C. et al.; Campbell and Flores, Suite 700, 4370 La Jolla Village Drive, San Diego, CA 92122 (US).

(81) Designated States: AM, AU, BB, BG, BR, BY, CA, CN, CZ, FI, GE, HU, JP, KE, KG, KP, KR, KZ, LK, LT, LV, MD, MG, MN, MW, NO, NZ, PL, RO, RU, SD, SI, SK, TJ, TT, UA, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ).

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Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

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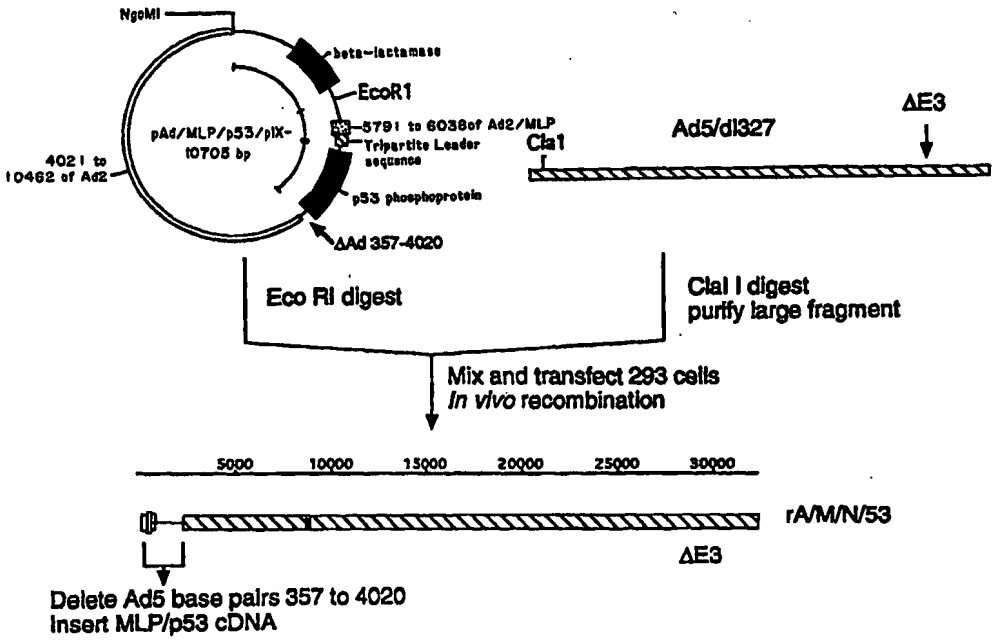
(54) Title: RECOMBINANT ADENOVIRAL VECTOR AND METHODS OF USE



(57) Abstract

This invention provides a recombinant adenovirus expression vector characterized by the partial or total deletion of the adenoviral protein IX DNA and having a gene encoding a foreign protein or a functional fragment or mutant thereof. Transformed host cells and a method of producing recombinant proteins and gene therapy also are included within the scope of this invention. Thus, for example, the adenoviral vector of this invention can contain a foreign gene for the expression of a protein effective in regulating the cell cycle, such as p53, Rb, or mitosin, or in inducing cell death, such as the conditional suicide gene thymidine kinase. (The latter must be used in conjunction with a thymidine kinase metabolite in order to be effective).

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INTERNATIONAL SEARCH REPORT

Internat ·l Application No
PCT/US 94/12235

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C12N15/86 C12N7/01 C12N5/10 A61K48/00 C07K14/47

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C12N C07K A61K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EMBO JOURNAL., vol.6, no.6, 1987, EYNSHAM, OXFORD GB pages 1733 - 1740 GHOSH-CHOUDHURY, G. ET AL. 'Protein IX a minor component of the human adenovirus capsid is essential for the packaging of full length genomes'	1-5, 7-10,13, 14
Y	see the whole document ---	18-31
A	GENE., vol.13, no.4, 1981, AMSTERDAM NL pages 375 - 386 DIJKEMA, R. ET AL. 'The gene for polypeptide IX of human adenovirus type 7' see the whole document ---	1
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
29 May 1995	07.06.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Chambonnet, F

Form PCT/ISA/210 (second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Internal Application No
PCT/US 94/12235

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	GENE., vol.13, no.4, 1981, AMSTERDAM NL pages 387 - 394 ENGLER J. A. 'The nucleotide sequence of poly peptide IX gene of human adenovirus type 3' see the whole document	1
Y	JOURNAL OF CELLULAR BIOCHEMISTRY, vol.SUP 0, no.17D, 17 March 1993 page 129 ZATLOUKAL, K. ET AL. 'Receptor-mediated cytokine gene delivery to tumor cells for generation of cancer vaccines' see abstract NZ 522	15-21
P,Y	JOURNAL OF CELLULAR BIOCHEMISTRY, vol.SUP 0, no.18A, 15 January 1994 page 237 GREGORY, R. J. ET AL. 'Tumor suppressor gene therapy of cancer: adenoviral mediated gene transfer of p53 cDNA into human tumor cell lines' see abstract dZ 307	15-21,25
T	WO,A,94 24297 (RHONE POULENC RORER) 27 October 1994 see the whole document	1
P,Y	CANCER GENE THERAPY, vol.1, no.2, June 1994 pages 107 - 112 SHEWACH, D.S. ET AL. 'Enhanced cytotoxicity of antiviral drugs mediated by adenovirus directed transfer of the herpes simplex virus thymidine kinase gene in rat glioma cells' see the whole document	18-31
Y	FR,A,2 688 514 (CNRS) 17 September 1993 see claim 3	15,16, 18,19, 23-25,31
Y	PROCEEDINGS OF THE NATIONAL ACADEMY OF SCIENCES OF USA., vol.87, November 1990, WASHINGTON US pages 8746 - 8750 VENKATESH, L. K. ET AL. 'Selective induction of cytotoxicity to human cells expressing human immunodeficiency virus type 1 tat by a conditionnally cytotoxic adenovirus vector' see the whole document	18,25

1

INTERNATIONAL SEARCH REPORT

...ernational application No.

PCT/US94/12235

Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. [X] Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

Remark: Although claims 16-24,26-30 and partially 15, as far as it concerns as in vivo method of treatment, are directed to a method of treatment of the human/animal body the search has been carried out and based on the alleged effects of the compound/composition.

2. [ ] Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. [ ] Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. [ ] As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. [ ] As all searchable claims could be searches without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. [ ] As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. [ ] No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

[ ] The additional search fees were accompanied by the applicant's protest.

[ ] No protest accompanied the payment of additional search fees.

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
WO-A-9424297	27-10-94	FR-A-	2704234	28-10-94
		AU-B-	6572194	08-11-94
FR-A-2688514	17-09-93	AU-B-	3757093	21-10-93
		CA-A-	2102302	17-09-93
		EP-A-	0593755	27-04-94
		WO-A-	9319191	30-09-93
		HU-A-	66486	28-11-94
		JP-T-	6508039	14-09-94
		NO-A-	934061	09-11-93